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Estimafed Radiological Inventory Sent from Test Area North to the Subsurface Disposal Area 1960—1993

Idaho Completion Project

Bechtel BWXT Idaho, LLC

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Idaho Completion Project
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ABSTRACT

This document reports an improved estimate of the inventory of radiological contaminants shipped from the Test Area North (TAN) from 1960 to 1993 and buried in the Subsurface Disposal Area, part of the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory. The four main sources of information used in analyzing the TAN waste are: (1) the Historical Data Task report, (2) the Supplement Recent and Projected Data Task report, (3) the Optical Imaging System shipping documents, and (4) the Radioactive Waste Management Information System database.

This report describes in detail the methodology for identifying, collecting, compiling, reviewing, and revising the radiological waste inventory from TAN. In addition, descriptions of the following are provided: (1) the TAN facilities or projects that shipped the waste (i.e., the waste generators), (2) processes by which waste was generated, (3) availability of waste disposal information, (4) sources of data, and (5) approaches for collecting and analyzing data.

Also included in this reevaluation is a correlation of the known shipments with the waste streams generated at TAN, including the burial locations and source of the waste from TAN; a radionuclide breakout for TAN waste; and an analysis of the inventories and waste forms that may affect remedial options.

This more inclusive inventory has been compiled to support the comprehensive remedial investigation and feasibility study being prepared by Operable Unit 7-13/14 for cleanup of the Subsurface Disposal Area.

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ACRONYMS

AEC	Atomic Energy Commission
ANP	Aircraft Nuclear Propulsion Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIDRA	Contaminant Inventory Database for Risk Assessment
CNOS	Carbon-Nitrogen-Oxygen-Sulfur
DOE	U.S. Department of Energy
EBR-II	Experimental Breeder Reactor-I1
FFACO	Federal Facility Agreement and Consent Order
G-M	Geiger-Muller
HDT	Historical Data Task
HTRE	Heat Transfer Reactor Experiment
IET	Initial Engine Test [Facility]
INEEL	Idaho National Engineering and Environmental Laboratory
INEL	Idaho National Engineering Laboratory
IWTS	Integrated Waste Tracking System
LLW	low-level waste
LMITCO	Lockheed Martin Idaho (former contractor of the INEEL)
LOCAs	Loss-of-coolant accidents
LOFT	Loss-of-Fluid Test
MAP	mixed activation products
MFP	mixed fission products
ML-1	Mobile Low-Power Reactor #1
NRF	Naval Reactor Testing Station
OIS	Optical Imaging System
ou	operable unit

PBF	Power Burst Facility
PM-2A	Portable Medium Nuclear Power Plant
RML	Radiological Measurements Laboratory
RPDT	Recent and Projected Data Task
RWMC	Radioactive Waste Management Complex
RWMIS	Radioactive Waste Management Information System
SDA	Subsurface Disposal Area
SL-1	Stationary Low-Power Reactor #1
SMC	Specific Manufacturing Capability
SNAPTRAN	Space Nuclear Auxiliary Power Transient Program
SVR	Soil Vault Row
TAN	Test Area North
TAN-607	TAN Hot Shop
TAN-633	TAN Hot Cells
TRU	transuranic waste
TSA	Transuranic Storage Area
TSF	Technical Support Facility
WIPP	Waste Isolation Pilot Plant

Estimated Radiological Inventory Sent from Test Area North to the Subsurface Disposal Area 1960—1993

1. INTRODUCTION AND BACKGROUND

This report documents the results of a reevaluation of radiological inventory from Test Area North (TAN) buried in the Subsurface Disposal Area (SDA) from 1960 through 1993. This report verifies the data and presents the methodology by which the data were developed. Since the original estimates were compiled—recorded in the "Historical Data Task" (HDT) and the "Recent and Projected Data Task" (RPDT; LMITCO 1995b and 1995c)—diligent and extensive additional searches have produced more information to allow more accurate estimation of contaminants from TAN buried in the SDA.

1.1 Objective

This risk analysis serves as the basis for the future comprehensive remedial investigation/feasibility study for cleanup of the Radioactive Waste Management Complex (RWMC). Models to support the risk analysis of the cleanup are based on the historical records of inventories and on investigations such as this report".Using all information available, the INEEL is quantifying the source terms for all of the radiological and hazardous contaminants buried in the SDA to support investigations under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

1.2 Overview

Previous efforts to quantify this inventory resulted in separate evaluations of two time periods: 1952 through 1983 (the HDT) and 1984 to 1993 (the RPDT). The latter period is covered by the current low-level waste (LLW) performance assessment (Case et al. 2000). The former period was governed by a variety of waste acceptance criteria; therefore, waste was disposed of under varying requirements for documentation and content. Results of the additional inventory effort documented in this report will be entered in the Contaminant Inventory Database for Risk Assessment [b](CIDRA) (INEL-95/0135, Supplement Rev 0 LMITCO 1995c), a comprehensive database of radiological and nonradiological contaminants buried in the SDA from 1952 to 1999.

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a. This study has been developed within the framework of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as implemented in the Federal Facility Agreement and Consent Order (FFACO) between the U.S. Department of Energy, the Idaho Department of Environmental Quality, and the U.S. Environmental Protection Agency.

b. The Contaminant Inventory Database for Risk Assessment (CIDRA) is the database holding information from the HDT, RPDT, and later supplements. The information in this report will be incorporated into the CIDRA database to reflect this reassessment of inventories for radiological waste streams from TAN during the HDT and RPDT time periods.

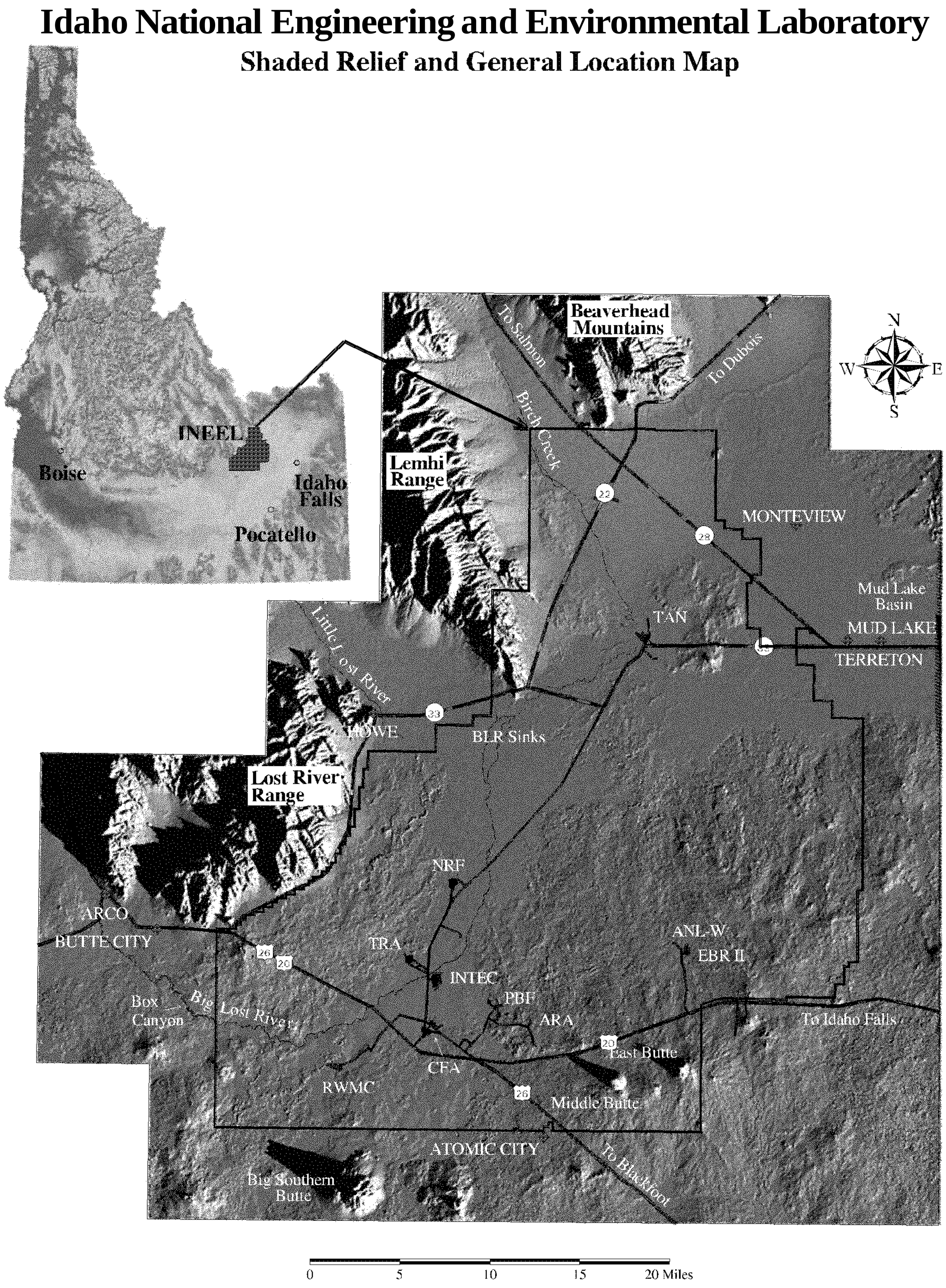

Figure 1. This map of the Idaho National Engineering and Environmental Laboratory shows the location of the Radioactive Waste Management Complex and other major facilities.

This report documents the reassessment of the two TAN disposal histories (HDT and RPDT) and revises estimates and activation of contaminants discharged from TAN to the SDA during the two time periods.

This report also addresses gaps—resulting from a lack of documented information—in the original estimates generated from the CIDRA database for the amount of contaminants discharged from TAN. Two of the INEEL databases (Radioactive Waste Management Information System [RWMIS] and the Optical Imaging System [OIS, INEEL, 20021) used in this evaluation also proved to be incomplete as sources of data for estimating complete nuclide-specific breakdown of contaminants of interest. Documentation in these sources usually indexed activation products, fission products, as well as actinides and transuranic (TRU) waste.

1.3 Brief History and Description of the Radioactive Waste Management Complex

Today, the Radioactive Waste Management Complex (RWMC) in the southwestern quadrant of the INEEL covers 71.6 ha (177 acres). This includes the administration area of approximately 8.9 ha (22 acres), the SDA, and the Transuranic Storage Area (established in 1970 at 23.3 ha [57.56 acres]; see Figure 2). Originally, the SDA was established at 5.26 ha (13 acres) in 1952 for disposal of solid radioactive waste. Defense waste with transuranic (TRU) elements began to come from Rocky Flats in 1954, and by 1957 the original SDA was nearly full. In 1958, the SDA was expanded to 35.6 ha (88 acres), which remained the same until 1988 when the security fence was relocated outside the dike surrounding the SDA and the current size of 39.3 ha (97.14 acres) was established.

From 1952 to 1970, low-level and transuranic radioactive waste was buried in pits, trenches, and soil vault rows excavated into a veneer of surficial sediment. This sediment is underlain by a thick series of basaltic lavas intercalated with sedimentary deposits. Waste containers may have been damaged by being compacted after sometimes random placement in pits and trenches. Since 1970, burial of low-level radioactive waste has continued and transuranic waste has been stored on above-ground asphalt pads in retrievable containers. Between 1952 and 1997, approximately 215 thousand m^3 of low-level and transuranic waste containing about 12.6 million Ci of radioactivity was buried at the SDA (French and Taylor 1998, page INEEL-3). Of this 12.6 million Ci, about 0.3 million Ci was transuranic radioactive waste. An inventory of annual amounts of 38 radioactive buried contaminants (Becker et al. 1998, Table 11) was updated for 25 radionuclides in Holdren et al. (2002, Table 11).

Between 1960 and 1963, the RWMC accepted LLW from private sources such as universities, hospitals, and research institutes. This service stopped in September 1963, when commercial burial sites became available for contaminated waste from private industry. When TSA became operational, asphalt pads were constructed on which TRU waste was stacked and then covered with plywood, plastic sheeting, and 1 m (3 ft) of soil. From 1975 to 1996, air-support buildings were used to protect recently received waste containers during stacking operations. These support structures were emptied in 1996 and decommissioned in 1998.

In the fall of 1988, the governor of Idaho banned all further shipments of TRU waste to the RWMC from out-of-state sources. Since 1985, waste disposals in the SDA have been limited to low-level radioactive waste from INEEL waste generators.

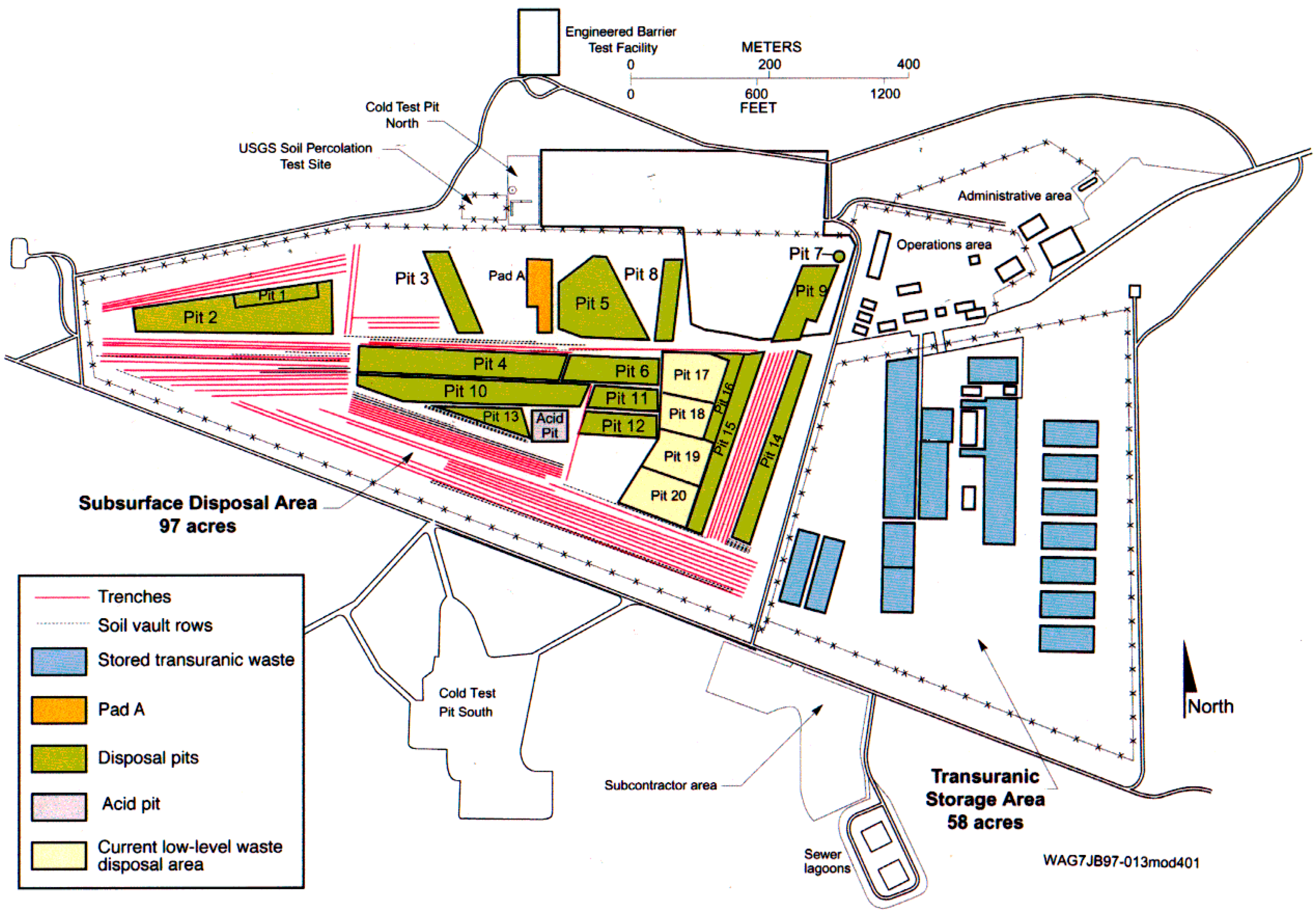

Figure 2. This map of the Subsurface Disposal Area shows the physical relationship of the various disposal locations and buildings.

In April 1999, the INEEL made its first TRU waste shipment to the Waste Isolation Pilot Plant (WIPP). The INEEL continued to make waste shipments to WIPP until October 2002, when the first 3,100 m^3 of waste had been removed ahead of schedule. The remaining 65,000 m^3 of waste will be processed by British Nuclear Fuels Ltd. and completely removed from the state by 2018, under terms of the 1995 Settlement Agreement.

1.4 Summary History and Description of Test Area North and Associated Generators of Waste

Test Area North (TAN) is at the north end of the INEEL, about 27 mi northeast of the Central Facilities Area. TAN was established in the 1950s by a joint program of the U.S. Air Force and Atomic Energy Commission that researched nuclear-powered aircraft. When this research ended, the area's facilities were converted to support other U.S. Department of Energy (DOE) research projects.

Test Area North is responsible for shipping 9.715E+03 m^3 of waste to the SDA from 1960 to 1993. During this 33-year period, 1,248 shipments (per the RWIMS database) were derived from 28 waste streams.

The following sections are a brief description of the three TAN facilities—Contained Test Facility, the Technical Support Facility (TSF), and the Water Reactor Research Test Facility—and their activities that have generated the majority of the waste shipped to the SDA. From studying these projects and their times of operation, the reevaluation and confirmation of the content of the waste streams has been made more accurate.

1.4.1 Test Area North—Contained Test Facility

The Contained Test Facility (Figure 3) is located at the west end of TAN. This facility includes the Containment and Service Building (reactor facility), an aircraft hangar, the Reactor Control and Equipment Building, and many support facilities.

The reactor research program at the Contained Test Facility ran experiments in loss-of-fluid accidents in nuclear power reactors. Buildings and structures that supported this program have been shut down over the past several years.' The major program now located at the Contained Test Facility is the Specific Manufacturing Capability, which develops and produces tank armor for the U.S. Army. All parts of the Contained Test Facility not used by the Specific Manufacturing Capability Program became inactive at the end of fiscal year 1997.

1.4.1.1 General Electric Aircraft Nuclear Propulsion Program (ANP). Test Area North was designed and constructed in the early 1950s to support the General Electric Aircraft Nuclear Propulsion (ANP) Program to test the concept of a nuclear-powered airplane. For 9 years, three versions of a full-scale nuclear-powered aircraft engine were tested (Wilks, 1962). The program support facilities consisted of the TSF, where TSF personnel had offices; the Initial Engine Test (IET) Facility; the Hot Shop (a large hot cell into which the engines could be moved for repair, assembly, and disassembly); and some smaller hot cells built to examine individual irradiated fuel pieces or other irradiated specimens.

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c. Preparation for deactivation of these buildings and structures began in 1996 and included documentation of some of the historic properties, including the Nuclear Aircraft Hangar. Other properties at Test Area North have also been determined to be potentially eligible for nomination to the National Register of Historic Places, and appropriate preservation activities will be considered in their disposition plans.

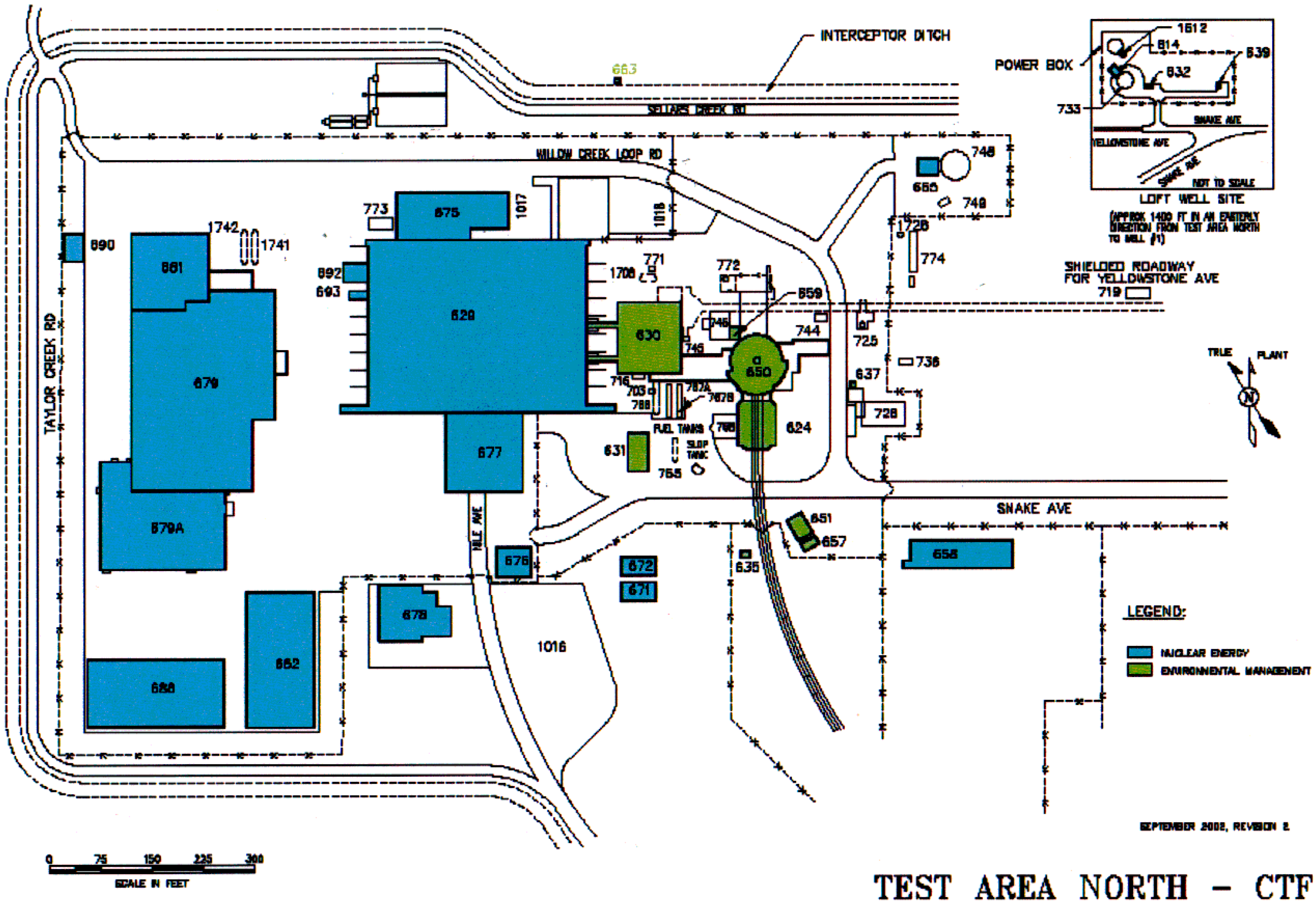


Figure 3. Site map of TAN-Contained Test Facility.

1.4.1.2 Loss-of-Fluid Test The area includes the Loss-of-Fluid Test (LOFT) Containment and Service Building, an aircraft hangar, the LOFT Reactor Control and Equipment Building, and many support facilities. The LOFT reactor, a scaled-down version of a commercial pressurized water reactor, was constructed between 1965 and 1975. The reactor was part of the Mobile Test Assembly mounted on a specially designed railroad flatcar located inside the domed containment vessel. Thirty-eight nuclear power tests were conducted on various accident scenarios, including the real accident at Three Mile Island (TMI), between 1978 and 1985.

The LOFT was inactivated in 1986, following completion of the LP-FP-2 experiment, which involved heating and melting a 100-rod experimental fuel bundle. The LOFT hangar was involved in the Hallam Decontamination and Decommissioning Project, which was conducted from 1977 to 1978. It included the following activities:

- Storing various components in the hangar at TAN/LOFT that were shipped to the INEL in 1968 from the dismantled Hallam Nuclear Power Facility near Lincoln, Nebraska.
- Moving the components to the IET for removal of the sodium from the components.
- Decontaminating the components, when feasible, for use in research and development and for disposal as surplus materials.
- Sending materials that could not be decontaminated to the SDA for disposal.

1.4.2 Test Area North—Technical Support Facility

The TSF (Figure 4) is the main administration, assembly, and maintenance area for Test Area North. Major programs now located at the TSF include the Three Mile Island Unit 2 Core Offsite Examination Program, the Process Experimental Pilot Plant (currently in shutdown condition), the Spent Fuel Program, and portions of the Specific Manufacturing Capability Program.

1.4.2.1 Initial Engine Test (ET). Testing the three Heat Transfer Reactor Experiment (HTRE) engines passed preheated air through the 93.4% enriched uranium core and jet engine components and released it to a 46-m (150-ft) high stack (Devens et al. 1958). Each test sequence was assigned an IET number. The HTRE power plants or test assemblies consisted of the Core Test Facility and the nuclear reactor. The core components were mounted on a structural steel platform.

The HTRE-1 engine (IETs #3, #4, and #6) had a reactor core of 37 fuel assemblies clad with nichrome (80% nickel and 20% chromium; Thornton et al. 1962). The engine operated exclusively on nuclear power for a total of 150.8 hours at high nuclear levels.

The HTRE-2 engine was used for the remaining 20 IETs, other than #13, #16, #18, and #25, from 1957 to 1961. All but one of these tests used a fuel/ceramic configuration of beryllium oxide (Flagella 1962). The remaining nonceramic test (IET #15) used a CR-UO_2-Ti (metallic), concentric-ring, fueled insert (Evans 1959). This reactor accumulated 1,299 hours of high-power nuclear operation.

The HTRE-3 engine was used for IETs #13, #16, #18, and #25 (Linn et al. 1962). Two modified 547 turbojet engines were operated by this reactor for 126 hours.

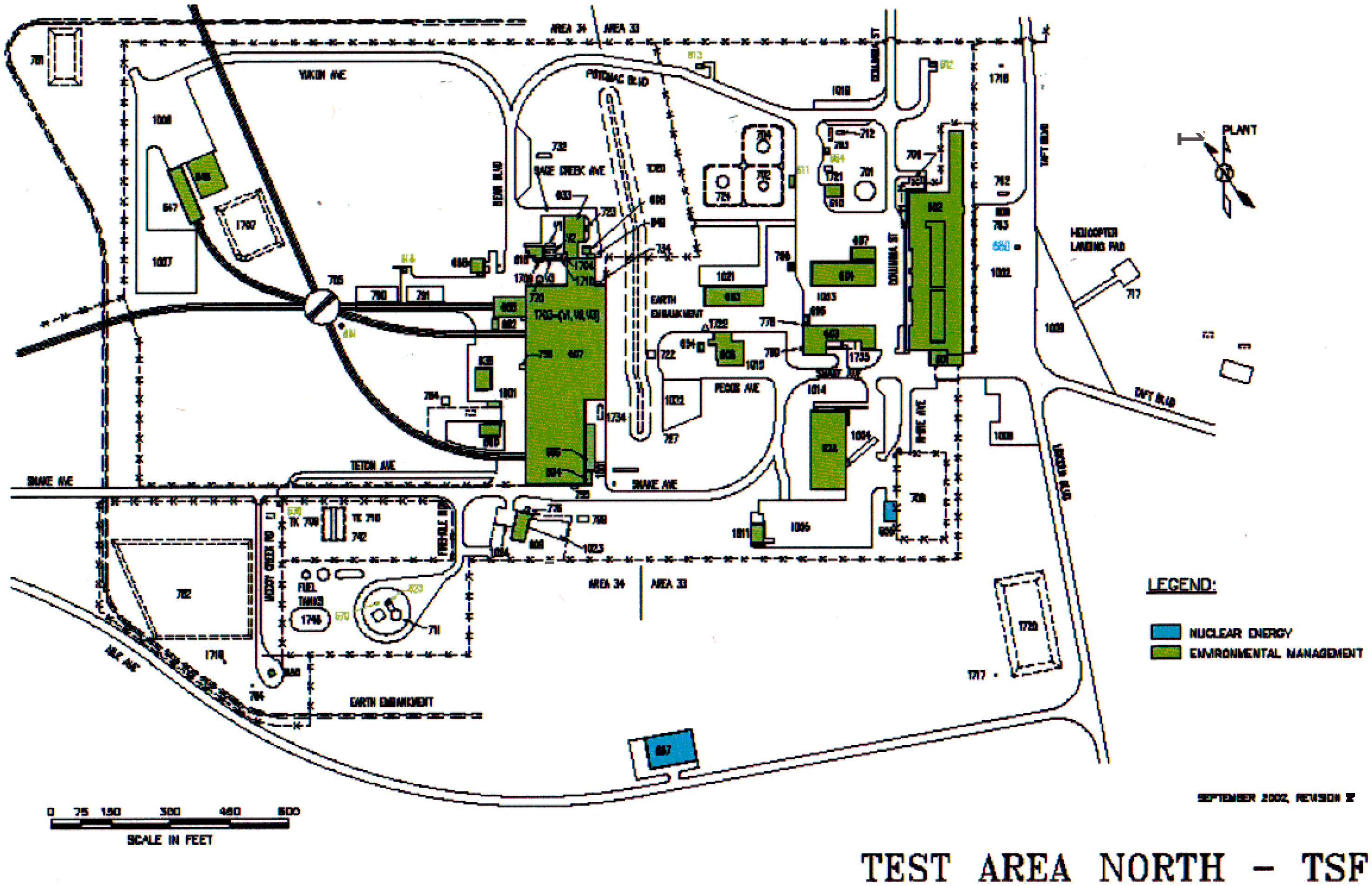


Figure 4. Area map of TAN-TSF.

1.4.2.2 *Space Nuclear Auxiliary Power Transient (SNAPTRAN) Program.*

The SNAPTRAN tests were criticality-destruct tests that purposely destroyed the nuclear core. In 1964, the first test used a fuel-moderator made of an alloy of zirconium hydride and 10% **wt** of 93% enriched uranium. The small core contained U-235 in 37 fuel rods and 464 gram-moles of H_2 reflected by beryllium inserts. The interstitial space among the fuel rods contained NaK.

In 1966, the second SNAPTRAN test configuration contained significantly more beryllium than the first test, but no NaK (Dietz, 1966). The internal beryllium reflector in both tests amounted to about 5,500 g, and the external beryllium reflector of the second test added an additional 11,000 g of beryllium.

1.4.2.3 *TAN Hot Shop (TAN-607) and Hot Cells (TAN 633).*

The Hot Shop is a large hot cell into which the ANP engines were moved for repair, assembly, and disassembly. Some smaller hot cells were also built for examining individual irradiated fuel pieces or other irradiated specimens. From December 1955, when nuclear testing of the HTRE-1 engine commenced, until after 1983, the majority of activity in the waste generated at TAN was shipped from the TAN Hot Shop (607) or the hot cells (633) to the SDA. The experiments and test assemblies were disassembled and examined at these facilities.

To account more accurately for the radioactive and hazardous waste sent to the SDA by these projects, the TAN Hot Shop and hot cell logs were also reviewed; thus, we know that from July 1962 until the 1970s, the TAN Hot Shop and hot cells were used principally for LOFT and miscellaneous minor examinations and tests for the Test Reactor Area and Power Burst Facility (PBF) with four exceptions. Those four exceptions are:

1,2. Examining the two reactor cores included in the SNAPTRAN tests that were conducted in (1) 1964 (Fletcher 1964; Kessler et al. 1965) and (2) 1966 (Cordes et al. 1976; Kessler et al. 1967)

3. Final disassembly and examination of the Mobile Low-Power Reactor No. 1 (ML-I) reactor core (Murphy et al. 1966)

4. Testing and examination of the Portable Medium Nuclear Power Plant (PM-2A) reactor vessel (Mousseau et al. 1967).

The disassembly and examination of each of the two reactor vessel components required disposing of radioactive material that was roughly equivalent in radioactivity to that of the Stationary Low-Power Reactor #1 (SL-I).

1.4.2.4 *Generation of the Waste.*

Most of the waste produced at TAN was a result of the specific test and evaluation programs discussed above. The decontamination, disassembly, evaluation, and discarding of the components of the tests generated a wide variety of waste that will be discussed in following sections of this report.

1.4.3 Test Area North—Water Reactor Research Test Facility

Although built in the late 1950s to study water-cooled nuclear reactors, Test Area North/Water Reactor Research Test Facility (Figure 5) was never used for nuclear-fueled experiments. Several projects investigating water reactor safety and instrument calibration were carried out at WRRTF.

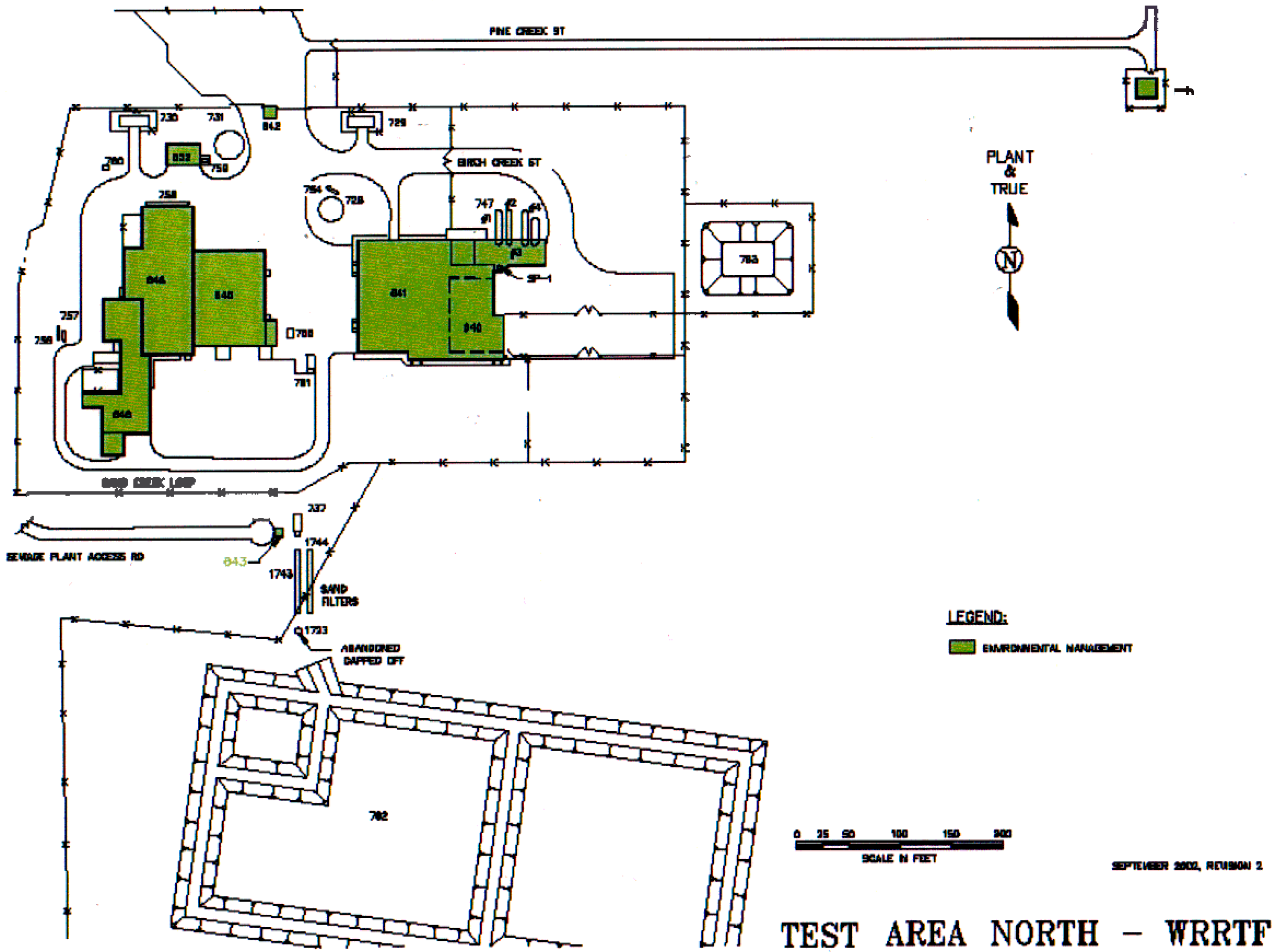


Figure 5. Area map of TAN-WRRTF.

1.5 Document Organization

The remaining sections in this report contain the following information:

Section 2—Background of the inventory analysis and a synopsis of the results and methods used to update information about the inventory of radionuclide waste from TAN and related facilities that was shipped to the SDA for disposal.

Section 3—Summary of the results of waste placement and its characteristics at the SDA.

Section 4—Approach and results of the reevaluation of the TAN waste stream, and resulting radionuclide breakout.

Section 5—Conclusion and analysis of the results from the reevaluation of the RPDT and the HDT relevant to TAN.

Section 6—References cited.

2. RECENT AND PROJECTED DATA TASK (RPDT) AND THE HISTORICAL DATA TASK (HDT)

2.1 Background

This section summarizes the original evaluation of radiological contaminants sent from TAN for burial in the SDA. The data presented in this section were taken from INEEL-95/0310 (formerly EGG-WM-10903) (LMITCO 1995a), HDT and INEL-95/0135 (LMITCO 1995b), and INEL-95/0135 Supplement (LMITCO 1995c) RPDT.

The three main contaminant categories used in the original analysis are fission products, activation products, and actinide waste. Each of these categories has attendant high-impact nuclides that are important for risk investigations of the SDA. This methodology is carried forward in the reevaluation presented in sections 2, 3, and 4 of this document.

Waste generated at TAN for disposal at the SDA during the RPDT time period consisted of remote-handled waste (generally with high gamma fields requiring safety precautions; e.g., transport in shielded containers) and contact-handled waste (LLW not requiring shielding). Remote-handled waste was buried in soil vaults, while contact-handled waste was buried in much larger pits because disposal in soil vaults ensured a higher level of shielding protection during remote waste handling. Compared to the activity of remote-handled waste, the relative net activity of contact-handled waste was a small fraction.

Contact-handled LLW was generated by routine facility operations and included metallic, combustible, and noncombustible waste streams. This waste originated from the ANP, HTRE, SNAPTRAN, and LOFT activities; primarily from TAN 607 (Hot Shop) and TAN 633 (Hot Cell) facilities.

2.2 Background Information on HDT and RPDT

The HDT and RPDT compile information for the baseline risk assessment under CERCLA for the SDA. Previous tasks had already generated some of this data; however, using personnel experienced with the facility, the HDT and RPDT attempted to more accurately depict the waste in the SDA by taking information from reports, shipping records, and various other databases.

The information collected was then entered in the Contaminant Inventory Database for Risk Assessment (CIDRA). The total activity (Ci) for each facility/location that disposed of radioactive waste at the SDA was then compared to the amount found in the RWMIS at the INEEL.

Collectors of data from TAN had two tasks: the first was to determine if the total curie content in RWMIS or Integrated Waste Tracking System (IWTS) databases accurately reflected the inventory shipped to the SDA. The second task was to scale the radiological terms in the database. The RWMIS and IWTS databases have entries for the radiological contaminates as unidentified alpha, unidentified beta-gamma, mixed activation products (MAP), mixed fission products (MFP), and depleted uranium-contaminated material.

2.2.1 HDT Radiological Process

The HDT covers the waste shipment period before 1983 (note that TAN only shipped waste from 1960 through 1993). HDT segregated the waste generated by TAN processes into 28 categories based on the location and type of waste sent to the SDA. The majority of the processes generating waste were activities associated with the Heat Transfer Reactor Experiment (HTRE), the SL-I, and the Space Nuclear Auxiliary Power Transient (SNAPTRAN).

To evaluate the curie content in RWMIS, the computer code "Radiological Safety Analysis Computer Program-5'' was used to calculate the activity of several TAN processes that generated waste sent to the SDA. These calculations were based on reactor operating parameters, report information, and personnel interviews with employees and former employees. Additionally, it was determined that the curie content of several waste shipments sent to the SDA was determined by the Geiger-Muller (G-M) approach, which meant taking multiple readings, averaging those measurements, then multiplying by a constant to convert the radiation reading into total curies. Based on the fill height and density, the G-M approach overestimated the curie content by a factor of two. Taking into account this average overestimation, our approach divided the curie content in the RWMIS database by two. Actual values were used when the overestimation in the G-M approach was not used.

Table 1 shows the total activity in the RWMIS and CIDRA databases for 1960 to 1983. The sum total of the RWMIS shipping record is approximately half the value of the best estimate when the additional 9,000 curies are entered for TAN.

Table 1. TAN's total activity in RWMIS compared to CIDRA.

	RWMIS Database Shipping Records Sum Total	CIDRA (without G-M correction)	CIDRA (G-M correction)
Total Activity (Ci)	6.3E+4	7.0E+4	3.5E+4

The majority of the activity (70%) listed in Table 1 results from the radionuclides found in structural components; these are cobalt, manganese, nickel, and iron. Cesium-137 and Strontium-90 account for 10% of the activity, while actinides such as transuranic radioisotopes account for less than 10 curies.

The reevaluation of these waste streams and waste shipments that make up the numbers identified in Table 1 is discussed in Section 4 of this document.

2.2.2 RPDT Radiological Process

The RPDT covers the shipping period after 1983. The RPDT divided TAN into two areas during this time period: the Specific Manufacturing Capability (SMC) facility and the rest of TAN.

TAN had 22 categories based on the location and type of waste sent to the SDA. From 1984 to 1993, the majority of waste generation came from activities associated with Three Mile Island, DOE, and LOFT. From 1994 to 1999, waste generated at TAN was primarily from operations in the decontamination shop and acid pits. Waste from the Specific Manufacturing Capability (SMC) was divided into four waste streams for the period 1994–1999 (SMC was not specifically mentioned previously). The waste generated at SMC was from processing depleted uranium.

The comparison of the RWMIS data total activity for TAN from 1984 to 1993 to CIDRA is shown in Table 2. The difference between data from RWMIS and from CIDRA is because of 300 curies from LOFT and 460 curies because of ^{90}Sr (without the G-M correction).

Table 2. TAN's total activity in RWMIS compared to CIDRA for 1984–1993.

	RWMIS Database Shipping Records Sum Total	CIDRA Database (without G-M correction)	CIDRA Database (G-M correction)
Total Activity (Ci)	3.7E+3	4.4E+3	2.2E+3

2.3 Waste Stream Assessment

The HDT listed 28 waste streams for 1960 through 1983, while the RPDT listed 22 waste streams sent to SDA for 1984 through 1993. These waste streams were not directly connected to any transportation shipments to the SDA during this time period. Table A1 (Appendix A) links HDT waste streams to radioactive shipments from TAN to the SDA and Table A2 (Appendix A) links the RPDT waste streams to the radioactive waste shipments from TAN to the SDA. The shipments identified in Table A1 make up 80% or more of the activity sent to the SDA from TAN in a particular year.

In this section, waste streams are linked to shipments. The four required linking pieces of information are:

- Place of origin (identified by the waste stream number)
- Year(s) generated (based on the HDT and RPDT)
- Project origin (identified by shipment number)
- Year of disposal (part of the shipment number).

If more than one waste stream from a building was generated during a year, the Data Collection Forms determine the waste stream with which the shipment should be associated.

Based on this information, we have identified eight HDT/RPDT waste streams that make up more than 80% of the activity sent to the SDA from 1960 through 1993; these waste streams are described in Table 3. These descriptions are based on the information from either OIS or RWMIS. Because the waste description did not explain the physical form of the waste, the last waste stream description (TAN-607-6R) was expanded, based on the Data Collection Forms for TAN-607-6R. The shipment time was also included in the description shown in Table 3.

Table 3. HDT/RPDT waste streams connected to shipments from TAN to the SDA.

Waste Stream	Description
TAN-607-2H	Contamination, contaminated parts from ANP HTRE-2 testing (IET #8 through IET #26). The waste was primarily stainless steel scrap metal, irradiated metal. This waste stream was generated 1957 through 1961.
TAN-607-3H	Activated SL-1 reactor parts contaminated during SL-1 reactor accident of Jan. 3, 1961, activated experiment, fuel elements. This waste was generated 1962 through 1963, consisted of core, loop components such as irradiated fuel, end boxes, stainless steel metal.

Table 3. (continued).

Waste Stream	Description
TAN-607-5H	Myriad manufacturing, assembly, health physics, Hot Shop activities associated with TAN programs. This waste was generated from 1967 through 1983. This waste stream contained a variety of radioactive waste such as scrap metal (stainless steel), resin, parts of tanks, concrete, and combustible materials.
TAN-633-2H	Myriad manufacturing, assembly, health physics, Hot Shop activities associated with TAN programs. This waste was generated from 1957 through 1961. This waste stream is primarily scrap metal including leaded materials.
TAN-633-3H	Metallurgical samples, specimens examined, discarded from Radiological Measurements Laboratory (RML), Hot Cells resulting from SL-1 accident of Jan. 3, 1961. This waste was disposed of in 1963. This waste is primarily paper, scrap metal, cement, and insulation.
TAN-633-4H	Metallurgical samples, specimens from examination of the Ml-1, PM-2A, the 2 SNAPTRAN systems. This waste was generated and disposed of from 1964 through 1966. This is a collection of various types of waste such as scrap metal, filters, control rod parts, reactor shielding, reflectors, and pipes.
TAN-633-5H	Hot Cells abutting TAN 607, with remote handling equipment for examining radioactive contaminated material. This waste was generated, disposed of from 1967 through 1970. This waste contains such material as core structures, piping, clad assemblies, stainless steel, and combustible waste.
TAN-607-6R	TAN Hot Shop, Hot Cell waste generated from 1984 through 1993. Hot Shop, Hot Cell waste weren’t segregated. Waste is a combination of items such as alloys of metal, end boxes, combustible material, fuel assembly shrouds, concrete, resin, and equipment from the Hot Shop/Hot Cell.

3. DATA ANALYSIS

This section compares the inventories, demonstrates level of agreement, and presents actual data or improved estimates. Four main sources of information were used in analyzing the TAN waste: (1) the HDT report, (2) the Supplement RPDT, (3) the Optical Imaging System (OIS) shipping documents, and (4) the RWMIS database.

3.1 Analysis Approach

The analysis of the data from TAN was carried out in four phases:

- Evaluation and comparison of inventories developed from RWMIS and the Form 110s (Waste Disposal Request and Authorization forms, (AEC Form 110; 1964) with those presented in the RPDT.

- Identification of waste shipment inventories resulting in a curie load per year greater than 80%.

- Assessment of inventories from the processing facility and disposal facility to confirm total amounts of curie load at disposal locations.

- Evaluation of inventories to determine waste forms that may affect options for remediation.

This assessment shows the level of correspondence between the two information systems used in the evaluation: the OIS (Optical Imaging System) and the RWMIS (Radioactive Waste Management Information System). Hard copies were retrieved to compare the OIS/TAN shipping manifests of the generating facilities with the manifests showing the disposal locations in the electronic database of RWMIS. In reassessing this information, (1) agreement between the two tracking information systems was determined, (2) whether a “level of significance” would emerge for 80% of the waste load through screening the data, and (3) the amount and identity of the waste loads and their location at the SDA (pits, trenches, and soil vault rows).

This analysis focused on the major waste streams—those that contained the greatest curie content—and made up the majority of the radiological inventory (>80%). The remaining percentage in any year have an inconsequential effect on the radiological inventory for the years analyzed.

3.2 Waste Shipment Analysis

To quantify the inventories, data were collected from hard copy shipping manifests from the generating facilities at TAN (OIS) and manifests showing disposal locations (RWMIS). An overall objective was to assess how well the two information systems agreed by identifying correspondences and differences.

Test Area North shipping manifests (OIS) covered 1960 through 1984; inventories of disposal locations (RWMIS) covered 1962 through 1993. Data from both were entered in spreadsheets to create the basis for evaluation using shipping units volume (m^3), weight (kg), and gross radioactivity (Ci). These spreadsheets were created shipment-by-shipment, and include shipping and disposal dates, disposal locations, and isotopic waste profiles whenever available.

Table 4 summarizes the comparison of the two information bases over the same time interval (1962–1984) and shows some discrepancies between the two information systems. Figures 6 through 9 show the best level of agreement overall (for the graphed data) between the two information systems.

Table 4. Information base comparison.

1962-1984	Total Shipments	Gross Radioactivity	Volume (m^3)	Weight (kg)	Total # Disp. Loc.
OIS	1015	5.5 Et4	7646	2.850 E+6	54
RWMIS	1072	5.9 E+4	7961	3.151 E+6	67

Figure 6 illustrates the closest agreement for the total number of waste shipments.

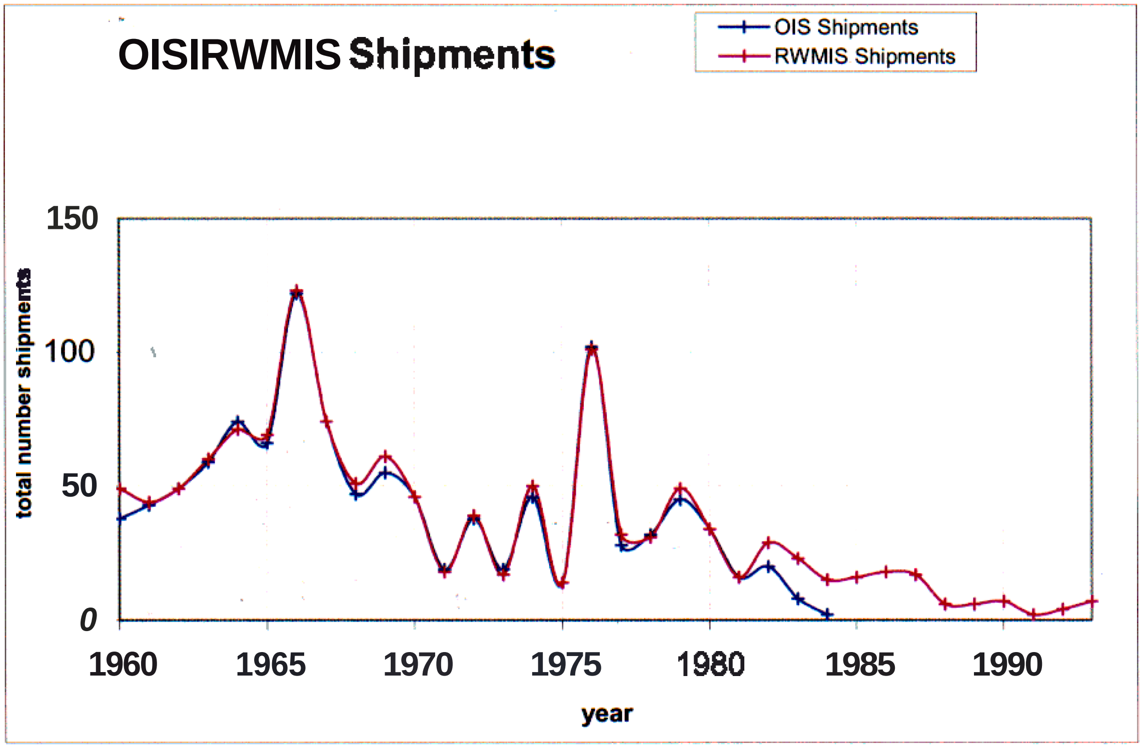


Figure 6. Optical Imaging System—R'WMIS shipments.

Figure 7 is a plot of gross weight (kg) from OIS and RWMIS records. These graphs illustrate a relatively good agreement of data between the two information systems for these parameters.

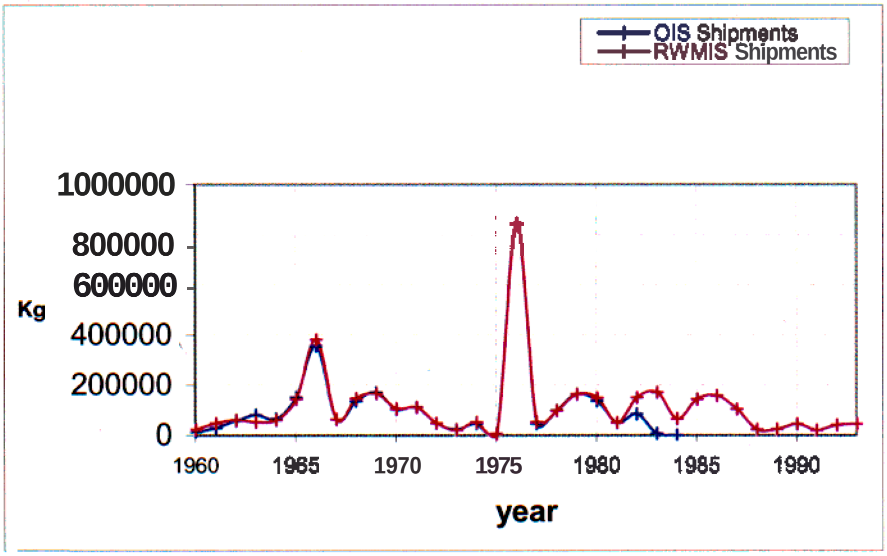


Figure 7. Optical Imaging System gross weight (kg).

Figure 8 shows there are differences between the two information systems for the volume shipped from 1960 to 1967, but the remaining years agree well. The reason for the differences during the early years was not identified.

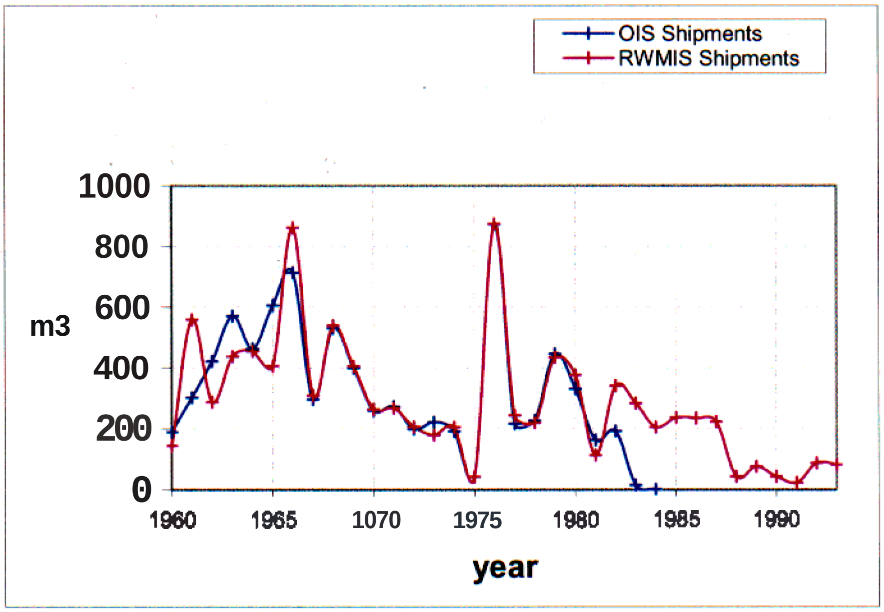


Figure 8. Optical Imaging System total volume (m^3).

Figure 9 shows trended data for total gross radioactivity (Ci) from 1960 to 1993. Although data from the two information bases are similar, the profile shows a wider range of variation than in previous figures. Reasons for the variations have not been identified,

Figure 9. Optical Imaging System/RWMIS gross activity (curies).

While there is good overall agreement between the two databases, some uncertainties remain because of the limitations of the documents on which this evaluation is based. For example, the date, shipment, or curie content of OIS 110 documents do not always correlate with RWMIS documents for the same shipment. Such discrepancies may be because of loss of hard copies of shipping manifests, misinterpretation of the handwriting of shipping manifests, or errors in rounding.

Prior 1960, a preliminary best estimate for TAN generated waste to the SDA is based on limited 1959 documentation (Table 5). The 1959 data indicates that 22 shipments were generated from TAN to the SDA, all from the GE-ANP (General Electric Aircraft Nuclear Propulsion project) facility. Those shipments contained 128 cubic meters with 33 curies of total gross activity. By comparison, TAN generated 1,248 shipments containing approximately 9,715 cubic meters with a total gross activity of approximately 66,394 curies during the RWMIS evaluation period. Based on the limited 1959 information, TAN waste streams were a relatively low impact contributor to the SDA before 1960.

Table 5. 1959 Hot Waste Logbook Summary.

TAN RADIOLOGICAL ESTIMATES INVENTORY

1959 HOT WASTE LOGBOOK- Book #1 of 7 Books (7530-286-6945)

Note: Partial ID is based on original RWMIS system documentation

Document Date/ID	Log Book Page	Shipment From:	Shipment To:	Originating Organization	Volume (m^3)	Gross Activity Curies
TANANP 4/21/59	3	TAN	trench 14	ANP		
TANGEANP 5/1/59	4	TAN	trench 14	GE ANP	7.075	0.5
TANGEANP 5/1/59	7	TAN	trench 14	GE ANP	6.113	0.5
TANGEANP 6/2/59	10	TAN	trench 14	GE ANP	8.490	5
TANGEANP 6/19/59	13	TAN		GE ANP		
TANGEANP 6/23/59	14	TAN	trench 14	GE ANP	5.660	0.2
TANGEANP 7/17/59	16	TAN	trench 14	GE ANP	9.169	2
TANGEANP 7/24/59	17	TAN	trench 14	GE ANP	9.905	
TANGEANP 8/7/59	20	TAN	trench 15	GE ANP	9.169	0.01
TANGEANP 8/14/59	21	TAN	trench 15	GE ANP	9.169	10
TANGEANP 8/18/59	22	TAN	trench 15	GE ANP	0.396	0.001
TANGEANP 8/25/59	23	TAN	trench 15	GE ANP	9.169	5
TANGEANP 9/1/59	25	TAN	trench 15	GE ANP	3.396	0.1
TANGEANP 9/1/59	27	TAN	trench 15	GE ANP	9.169	2
TANGEANP (1)9/29/59	31	TAN	trench 15	GE ANP	9.169	0.02
TANGEANP (2)9/29/59	31	TAN	trench 15	GE ANP	9.169	5
TANGEANP (1)10/13/59	33	TAN	trench 15 &/or 16	GE ANP	2.264	0.01
TANGEANP (2)10/13/59	33	TAN	trench 15 &/or 16	GE ANP	2.264	0.01
TANANP 10/27/59	34	TAN	trench 16	ANP	5.094	0.83
TANANP 11/10/59	36	TAN		ANP	0.991	1.5
TANANP 11/20/59	37	TAN	trench 16	ANP	7.646	0.5
TANANP 12/22/59	41	TAN	storage disposal pit	ANP	4.587	0.004
TOTALS		22			128.06	33.19
Totals OIS 60-84		1096			8137.82	56229.60
Totals RWMIS 60-93		1248			9714.80	66393.66
% of 59/60-93 (RWMIS)		1.76			1.32	0.05

3.3 Percent of Waste Shipments >100 Curies

To determine if a "level of significance" for gross radioactivity would emerge for TAN-generated waste shipments made to the SDA, a screening criterion was applied to the OIS/RWMIS data gathered from 1960 to 1993. Waste shipments having more than 100 Ci per shipment were identified to determine their relative percent of the total curie waste load for all shipments to the SDA.

Table 6 shows data for shipments having more than 100 (Ci) per shipment. In RWMIS, detailed information was unavailable before 1962; the OIS system shows that there were no shipments having more than 100 Ci per shipment in 1961, 1975, 1976, and the remaining years of the reporting period of 1979 through 1984. Figures 10 and 11 show an emerging level of significance. Approximately 10% of the total waste shipments contained –95% of the gross radioactivity (Ci). Shipping years 1960 through 1979 contained most of the waste load in terms of both number of shipments (1,048 shipments for RWMIS vs. 1,016 shipments for OIS) and gross radioactivity shipped (5.623+4 Ci/OIS), according to receipts at the SDA (5.600+4 Ci/RWMIS).

The RWMIS 1960–1979 time period accounts for approximately 94% of the total waste load in curies shipped. The OIS system accounts for approximately 99% of the total waste load in (Ci) for 1960–1979. Comparing the percent of total curie load for both the OIS and RWMIS information systems through 1979 shows only small differences in percentages; however, note that there are differences in the actual amounts calculated from each system (see Table 6).

3.4 Radiological Breakout of the 80% Curie Load for Waste Shipments from TAN

In the previous evaluation (more than or equal to 100 Ci/shipment), several years were not represented because OIS and RWMIS information indicated that shipments during those years did not have a curie load meeting the cut-off criterion. An annual load identification of 80% was set to provide the best accounting of waste shipments to the SDA. In order to represent the missing years (Table 6), a second evaluation used the 10 highest curie loads for shipments during those years. This second evaluation indicates that shipments having less than or equal to (>/=) 80% of the total gross radioactive (Ci) waste load fill the gaps of missing representation (see Table 7).

Using the >/= 80% screening criterion, the OIS data show that an average of about 22% of the shipments represent about 89% of the total waste load. Using the same criterion, the RWMIS database shows that an average of approximately 27% of the waste shipments contained approximately 91% of the gross radioactive waste load received at the SDA. Total gross radioactivity levels ranged from 1.98 E+3 (Ci) in 1980 (per RWMIS) to 9.7 E-3 (Ci) in 1984 (per OIS).

Although these percentages of the totals are in relative agreement with each another, it is the ranges of differences of recorded shipments and gross activity levels that become apparent through the screening criteria (Table 7). There are some disagreements in the values reported by both systems for the same time period as well as missing information. For example, in 1983 the gross radioactivity levels between reported values in OIS and RWMIS varied by 24 curies and in 1979 the OIS database showed eight screened shipments containing a total of 11 (Ci) in waste load, but the RWMIS recorded no shipments received for burial.

Table 7 and Figures 12 and 13 show that for the 80% curie load criterion, at least 24% of the shipments carried approximately 90% of the waste load. This is different from the data in Table 6 where the > 100 curie criterion showed ~ 10% of the shipments carried –95% of the waste load (see Section 3.3).

Table 6. Percentage of yearly totals for waste shipments having greater than 100 curies; RWMIS-OIS percentage comparison-first screen level.

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
RWMIS														
Total yearly shipments	—	—	49	60	71	69	123	74	51	61	46	18	39	17
# screened shipments > 100 Ci	—	—	5	7	4	7	7	9	5	6	5	1	3	2
% screened shipments > 100 Ci	—	—	10	12	6	10	6	12	10	10	11	6	8	12
Totals > 100 Ci	—	—	1.241E+04	4.800E+03	3.370E+03	1.298E+03	3.517E+03	1.415E+03	4.350E+03	5.450E+03	1.375E+03	1.006E+03	2.340E+03	1.970E+03
Total yearly gross activity (Ci)	—	—	1.273E+04	5.265E+03	3.694E+03	1.454E+03	3.959E+03	1.783E+03	4.473E+03	5.590E+03	1.395E+03	1.036E+03	2.368E+03	1.988E+03
% shipments > 100 Ci	—	—	97.52	91.17	91.23	89.24	88.84	79.38	97.25	97.49	98.54	97.06	98.84	99.10
OIS														
Total yearly shipments	38	43	49	59	74	66	122	74	47	55	46	19	38	19
# screened shipments > 100 Ci	4	—	5	7	6	6	6	10	4	6	4	2	2	2
% screened shipments > 100 Ci	11	—	10	12	8	9	5	14	9	11	9	11	5	11
Totals > 100 Ci	6.000E+02	—	1.650E+04	4.800E+03	3.616E+03	1.132E+03	3.250E+03	1.915E+03	2.850E+03	1.850E+03	1.100E+03	2.215E+03	1.131E+03	1.970E+03
Total yearly gross activity (Ci)	1.198E+03	—	1.673E+04	5.201E+03	3.879E+03	1.364E+03	3.519E+03	2.228E+03	2.953E+03	1.992E+03	1.121E+03	2.247E+03	1.159E+03	2.067E+03
% shipments > 100 Ci	50.08	—	98.62	92.30	93.22	82.99	92.34	85.96	96.51	92.86	98.16	98.59	97.63	95.31

	1974	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
RWMIS																						
Total yearly shipments	50	50	14	101	32	31	49	34	16	29	23	15	16	18	17	6	6	7	2	4	7	—
# screened shipments > 100 Ci	5	5	—	—	2	3	1	—	—	—	—	—	—	—	1	—	—	4	—	2	—	—
% screened shipments > 100 Ci	10	10	—	—	6	10	2	—	—	—	—	—	—	—	6	—	—	57	—	50	—	
Totals > 100 Ci	6.400E+03	6.400E+03	—	—	1.300E+03	3.000E+03	2.000E+03	—	—	—	—	—	—	—	3.400E+02	—	—	2.642E+03	—	3.433E+02	—	—
Total yearly gross activity (Ci)	6.736E+03	6.736E+03	—	—	1.394E+03	3.017E+03	2.013E+03	—	—	—	—	—	—	—	3.586E+02	—	—	2.647E+03	—	3.463E+02	—	—
% shipments > 100 Ci	95.01	95.01	—	—	93.25	99.44	99.34	—	—	—	—	—	—	—	94.81	—	—	99.78	—	99.13	—	
OIS																						
Total yearly shipments	46	46	14	102	28	32	45	34	16	20	8	2	—	—	—	—	—	—	—	—	—	—
# screened shipments > 100 Ci	5	5	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
% screened shipments > 100 Ci	11	11	—	—	7	6	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—
Totals > 100 Ci	6.400E+03	6.400E+03	—	—	1.300E+03	2.000E+03	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total yearly gross activity (Ci)	6.655E+03	6.655E+03	—	—	1.394E+03	2.018E+03	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
% shipments > 100 Ci	96.16	96.16	—	—	93.26	99.13	—	—	—	—	—			—	—	—	—	—	—	—	—	—

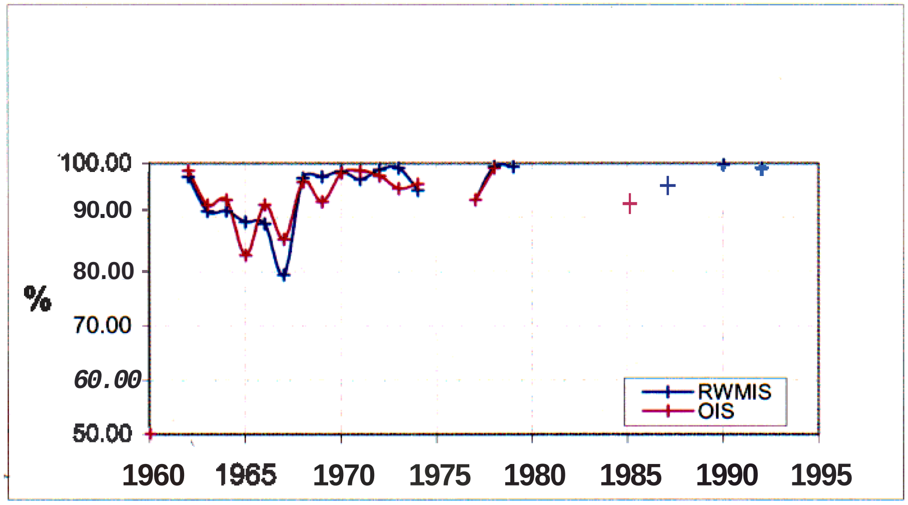


Figure 10. RWMIS-OIS % of total waste load > 100 Ci/shipment.

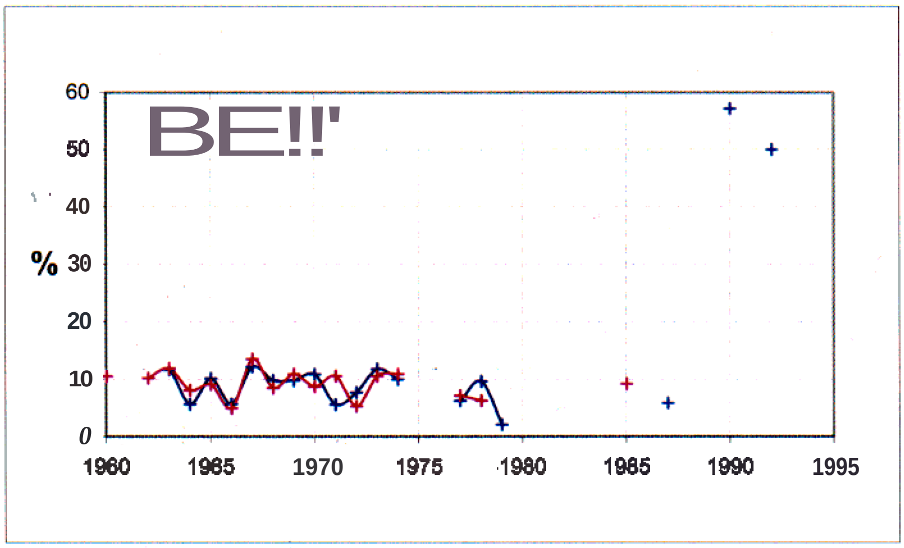


Figure 11. RWMIS-OIS % of total shipment > 100 Cilshipment.

Table 7. Percentage of yearly totals greater than 80 % of the waste load for (Ci) within the highest 10 gross radioactivity for years that had shipments > 80% waste load with < 100 Ci/shipment.

	1960	1961	1975	1976	1979	1980	1981	1982	1983	1984	1985	1986	1988	1989	1991	1993
RWMIS																
total yearly shipmcnts	—	—	14	101	—	34	16	29	23	15	16	18	6	6	2	7
# scrccncd shipmcnts > 80% Ci load	—	—	1	55	—	2	2	2	2	3	5	4	2	2	2	1
% scrccncd shipmcnts > 80% Ci load	—	—	7	55	—	6	13	7	9	20	31	22	33	33	100	14
totals within ncxt highcst 10 gross Ci	—	—	2.340E+01	2.56E+02	—	1.98E+03	5.00E-01	5.020E+00	3.12E+01	1.96E+00	1.57E+01	1.39E+01	1.15E+00	6.63E+01	7.50E-03	2.12E+02
yearly gross activity (Ci)	—	—	2.36E+01	2.98E+02	—	2.29E+01	5.89E-01	6.209E+00	3.66E+01	2.13E+00	1.74E+01	1.67E+01	1.17E+00	6.81E+01	7.50E-03	2.16E+02
% =/> 80% Ci	—	—	99.19	85.83	—	85.39	84.87	80.85	85.36	91.98	90.48	83.08	98.39	97.35	100	98.38
OIS																
total yearly shipmcnts	38	43	14	102	45	34	16	20	8	2						
# scrccncd shipmcnts > 80% Ci load	9	11	1	52	8	2	2	3	1	1	OIS avg. %	RWMIS avg. %				
% scrccncd shipmcnts > 80% Ci load	24	26	7	51	17	6	13	13	13	50	22	27				
totals within ncxt highcst 10 gross Ci	9.70E+02	1.13E+02	2.340E+01	2.56E+02	1.11E+01	1.95E+01	5.00E-01	9.23E-01	7.21E+00	9.70E-03	—	—				
yearly gross activity (Ci)	1.20E+03	1.38E+02	2.36E+01	2.98E+02	1.28E+01	2.28E+01	5.89E-01	1.02E+00	7.24E+00	1.01E-02	—	—				
% =/> 80% Ci	80.97	81.61	99.19	85.83	86.69	85.48	84.87	90.64	99.62	96.04	89	91				

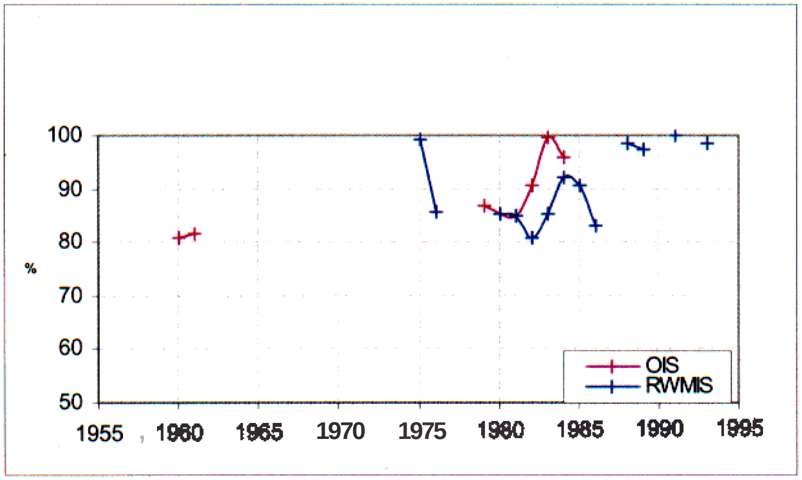


Figure 12. Optical Imaging System RWMIS >80% waste load for years with less than 100 Ci/shipment.

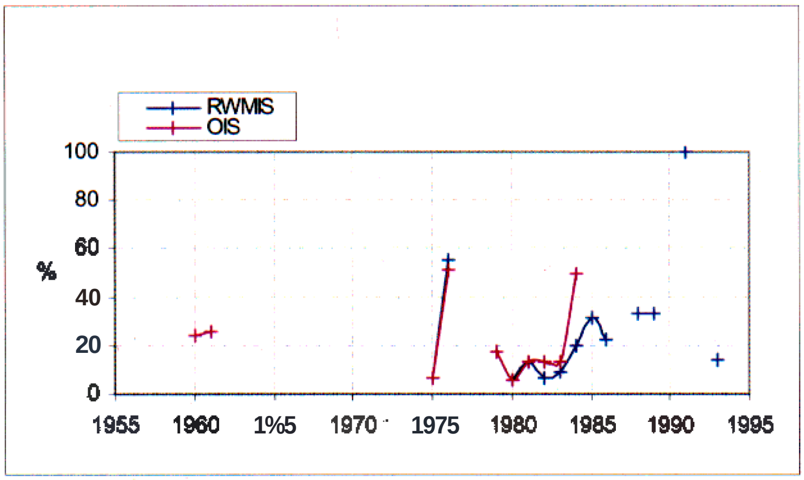


Figure 13. Optical Imaging System RWMIS % shipments >80% waste load for years with less than 100 Ci/shipment.

3.5 Disposal Locations Documented for Waste Shipments from TAN

Because the RWMIS information system is more complete in terms of years of coverage (containing a larger data population of the waste stream) and waste disposal locations, RWMIS information was used to identify disposal locations at the RWMC/SDA. Furthermore, the entire database was used in this section without applying the criteria used in Sections 3.3 and 3.4.

The following figure (Figure 14) illustrates the percentage of waste shipments from the individual TAN facilities to the SDA. Note that two facilities produced almost 95% of all shipments processed from routine operations at TAN. The Hot Shop (TAN-607 – Figure 15) shipped almost 80% of the waste shipments. The Hot Cells (TAN-633) shipped nearly 14% of the total waste shipments. Waste shipments originating from other TAN facilities were sent to the SDA, but typically represented 1% or less of the total waste load processed from TAN.

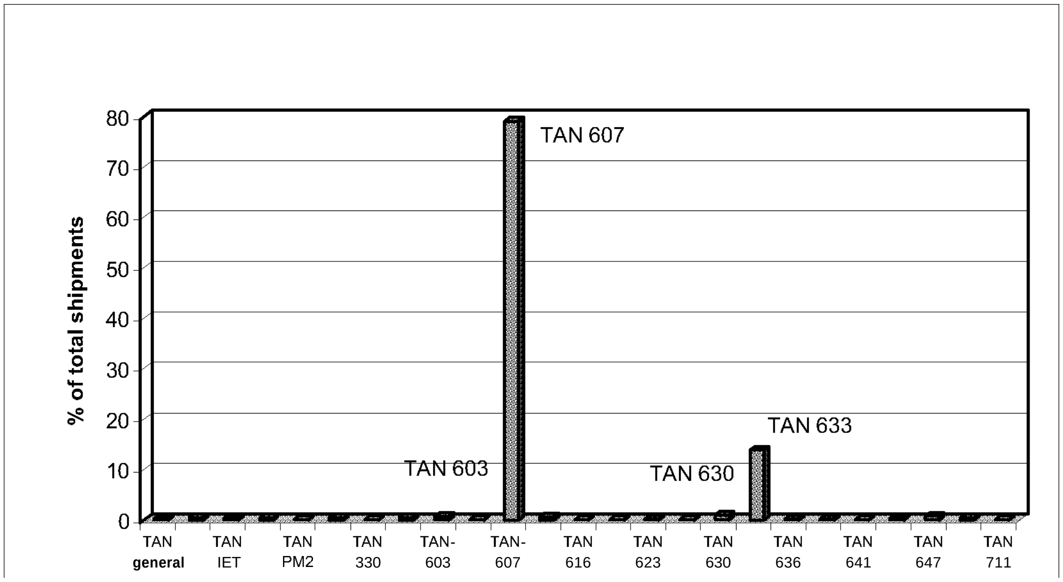


Figure 14. Total waste shipments from TAN facilities 1960–1993.

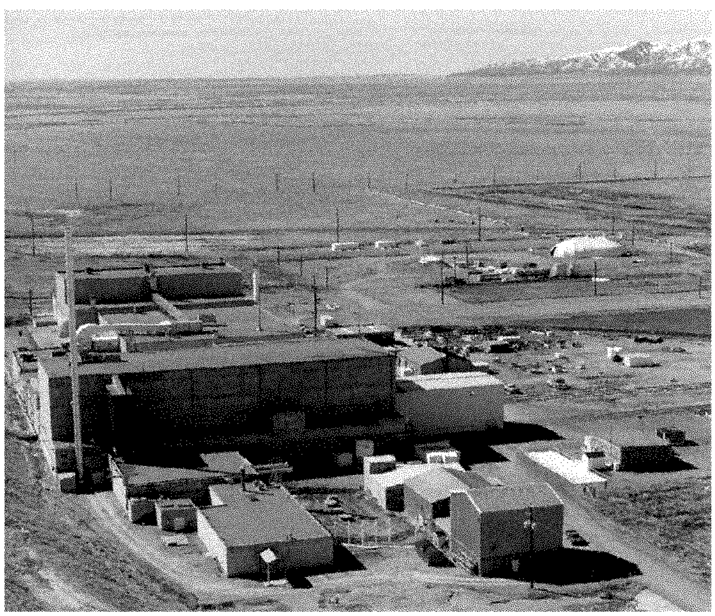
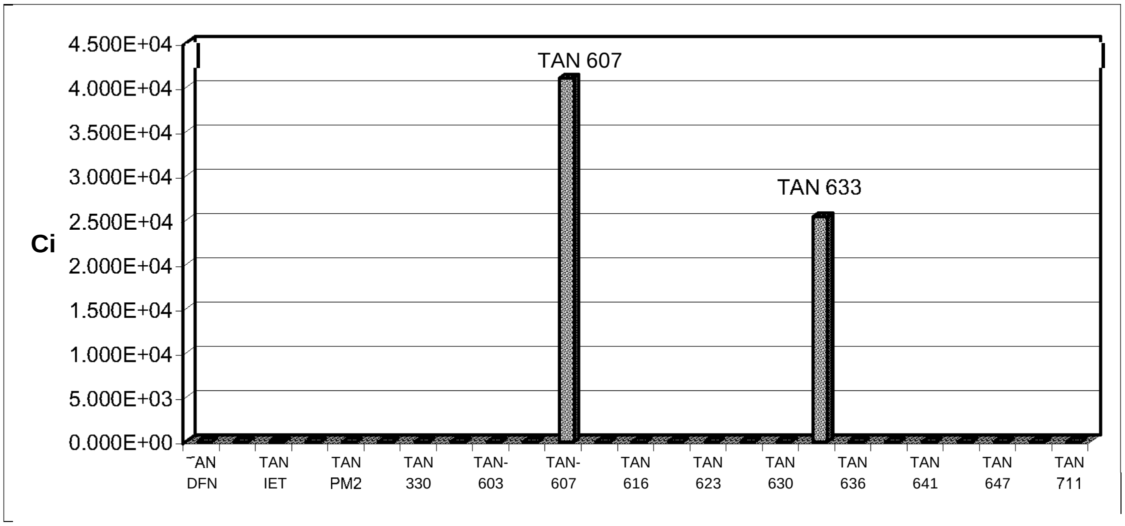


Figure 15. Hot Shop TAN-607.

TAN-607 and TAN-633 were also the major originators of gross radioactive waste compared to other TAN facilities (see Figure 16). Combined, these two facilities produced 6.638 E+4 (Ci) of the total 6.639 E+4 (Ci) irradiated waste stream. The peak year for gross activity from TAN-607 was in 1962. After 1962, the total curie load from TAN-607 was intermittent: it was greatly reduced until 1970, escalated to 6.735 E+03 in 1974, then became intermittent again with a final significant producing year in 1990 with 2.647 E+3 (Ci) shipped. The curie load from TAN-633 averaged 3.135 E+3 (Ci) per year from 1963 to 1970 and had little waste load production after 1970.



: 16. Total gross radioactivity (Ci) generated by TAN facilities 1960–1993.

Figure 17 shows percentage of total volume (m^3) buried at the SDA from TAN facilities.

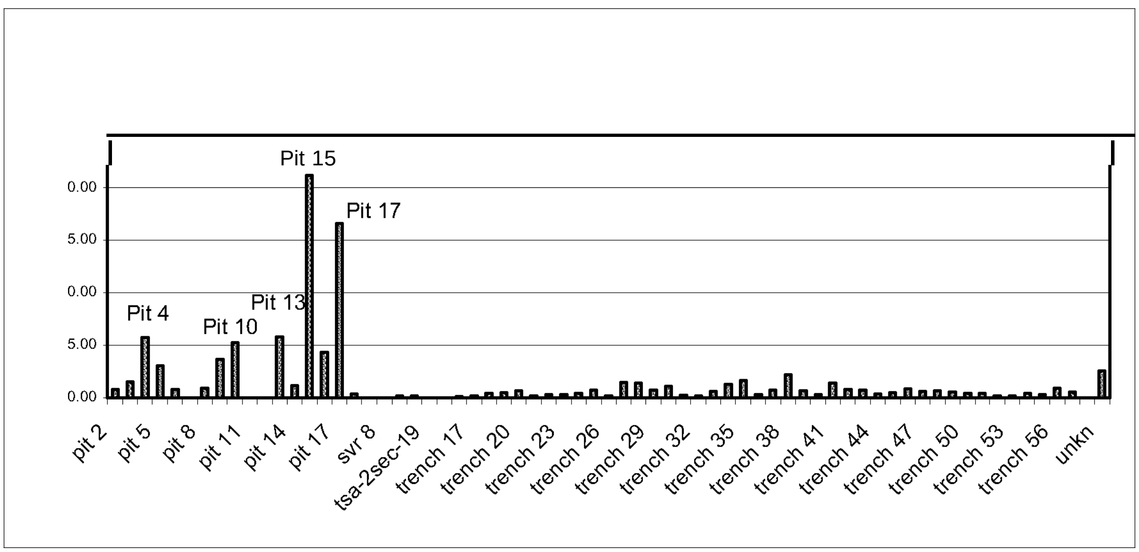


Figure 17. Percent of total waste load SDA received by volume (m^3) generated by TAN facilities.

Pit 15 (Figure 18) and Pit 17 (see Figure 19 location map of the SDA) received approximately 40% of the documented waste stream by volume. Pits 4, 10, and 13 each received approximately *5%* of the total for an additional 15% accumulation. These five pits received 65% of the volume buried at the SDA with the remaining waste more or less evenly distributed throughout the other identified disposal locations (primarily trenches). Although low in percentage by comparison to the primary locations, the disposal location of a surprising 2.5% of the volume handled is unknown.

Figure 18. Waste placed in Pit 15.

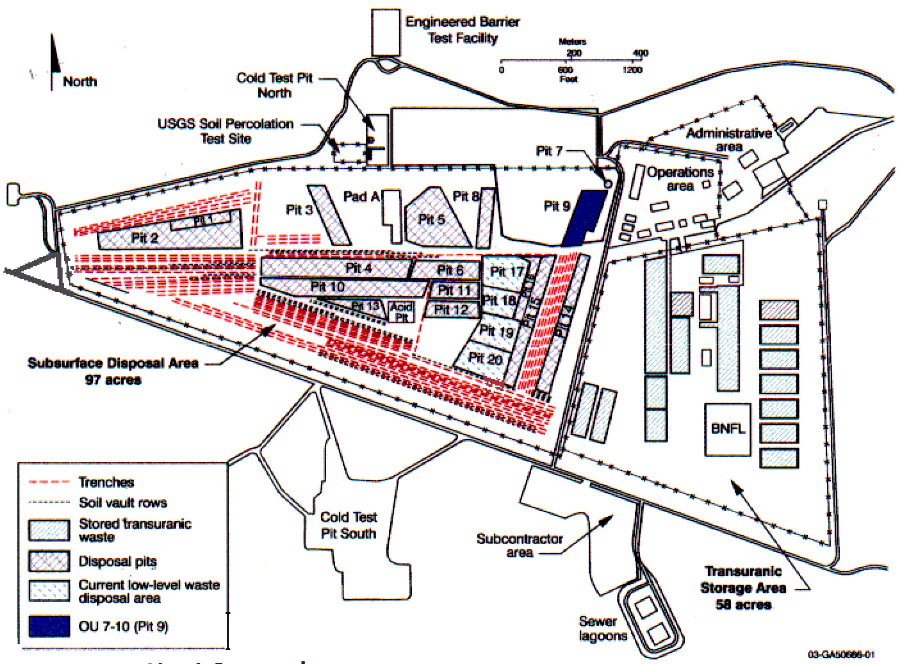


Figure 19. Location map of burial sites in the SDA.

Figure 20 illustrates percentage of total gross radioactivity processed for burial at the SDA from TAN. In contrast to the percentage of waste sent to the SDA by volume depicted in Figure 16—showing that only *two* disposal locations received the larger volume amounts—Figure 20 shows a greater distribution of the irradiated waste stream in the SDA. Three trenches (26, 49, and 57) received approximately 36% of the curie load, with mother seven locations receiving an additional 31%. These ten locations received for burial approximately 67% of the curie waste load from TAN compared to five locations receiving 65% by volume.

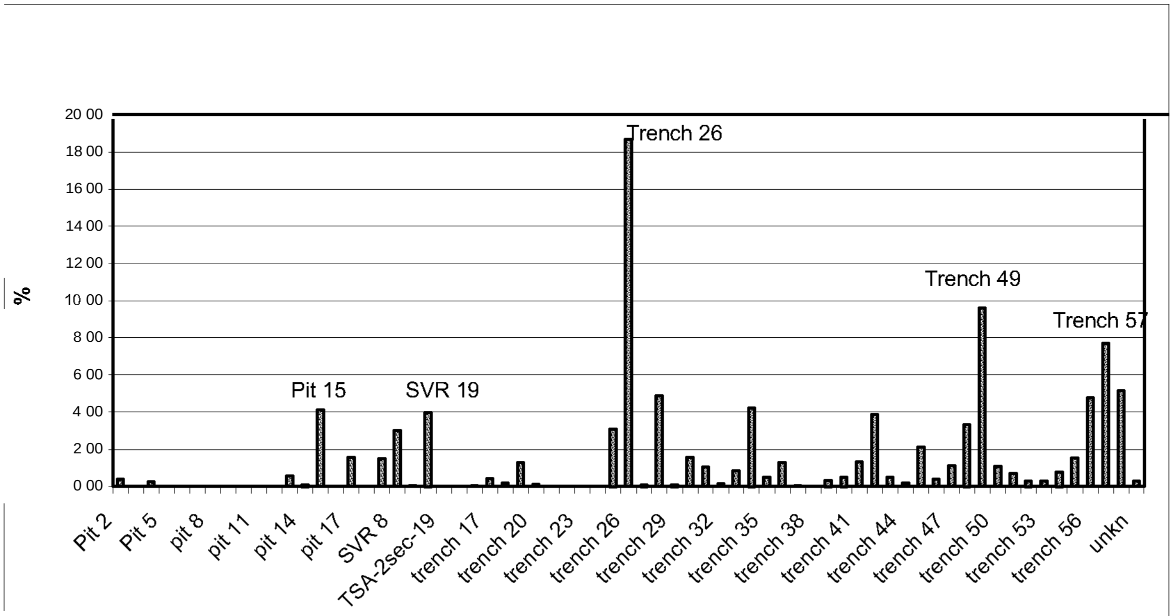


Figure 20. RWMIS% of gross radioactivity by trench or pit that SDA received from TAN.

Whether this was routine disposal designed to distribute irradiated waste throughout the SDA or to distribute by volume is unknown. The SDA was handling routine waste from other INEL facilities as well as that generated by TAN. It appears—from the yearly disposal pattern of waste shipments and curie load exhibited in the spreadsheets—that before a burial location was completely full of waste, disposal was shifted to the next location in sequence; therefore, TAN-generated waste became distributed throughout the burial grounds instead of being confined to fewer, concentrated locations.

3.6 Waste Forms Which May Affect Remedial Options

This section identifies waste forms that—because of their radiological or hazardous nature—may affect remediation alternatives. Also identified in this section is the location of these waste forms in the SDA. This identification was made in support of CERCLA investigations that are part of the cleanup effort at RWMC.

In our analysis, three aspects of the waste shipments were used to identify waste forms of potential interest:

- Potential health or safety concerns
- The size and weight of the item being disposed of
- An unusually high radiological presence.

Table B1 (Appendix B) lists these shipments by year. The column on the right lists the reason for potential concern. Also identified in the table is the location in which these shipments were buried.

The 133 waste shipments (Table 8) identified as potentially affecting remedial options have a combined weight of over 1.2 million pounds and a curie content of over 18,000. The concern with the curie content is not the total number of curies, but rather that these were all wastes from fuel and reactor processes, indicating that mixed fission products may make up the majority of the curie load. The presence of mercury, NaK, beryllium, and gas cylinders also affect questions of health and safety.

Table 8. Waste shipments identified as potentially affecting remedial options.

	Health/Safety Concern	Size Concern	Radiological Concern
Number of Shipments	30	62	41

Tables 9 and 10, respectively, show the 25 largest and heaviest 01s-listed shipments ordered by volume and weight. According to the OIS database, at least eight shipments weighed over 20 tons (18,160 kg). The largest was mixed fission products from SL-I, weighed 38 tons (34,500 kg), and occupied 2,486 ft^3 ($70m^3$). Although these items were shipped from TAN facilities, their origins are not necessarily related to programs conducted at TAN since the TAN Hot Shop and Hot Cells inspected materials from other Site locations as well as shipments from off-Site.

Environmental, health, and safety issues other than radiological may also be important concerns during waste recovery. Since lead was often used in making the shipping container to shield against certain types of radiation—Table 11 identifies 01s-listed shipments having lead on the manifest—the potential for human exposure as well as environmental release of lead must be considered in recovering waste.

Table 9. Largest 25 01s-listed shipments from TAN to the SDA. ranked bv volume.

Document ID	Shipment From:	Shipment To:	Rank	Volume ft^3	Volume m^3	Weight Kilograms (kg)	Composition	Container Type
TAN607SR005/17/661	TAN-607	PIT 4	1	5750	162.82	18160.00	Schedule 140 steel pipe, refueling support structure	Transportationltractor trailer
TAN607SR011/09/71830	TAN-607	PIT 13	2	3600	101.94	21792.00	Master boiler	—
TAN607SR004/15/70800	TAN-607	PIT 10	3	3145	89.056	1135.00	Metal	Frame and sheet metal
TAN633SR002/28/63810	TAN-633	PIT 4	4	2486	70.396	34504.00	Mixed fission products from SL-1	Cask
TAN607SR008/20/68820	TAN-607	PIT 9	5	2376	67.281	13620.00	PM-2A waste	2 metal containers
TAN607SR005/25/73110	TAN-607	PIT 13	6	2240	63.43	7264.00	Tankerltrailer	—
TAN607SR008/22/68810	TAN-607	PIT 9	7	2210	62.58	19068.00	PM-2A equipment	Skidllo boy
TAN607SR008/26/68800	TAN-607	PIT 9	8	1764	49.951	14528.00	PM-2A equipment	1 skid
TAN607SR008/23/68810	TAN-607	PIT 9	9	1436	40.663	19068.00	PM-2A equipment	2 skids
TAN607SR008/24/71800	TAN-607	PIT 13	10	1392	39.417	18160.00	Boiler and cooling tank	—
TAN607SR001/15/63810	TAN-607	TRENCH 28	11	1350	38.228	113.50	Fiber barrels	—
TAN607SR008/22/68820	TAN-607	PIT 9	12	1192	33.754	7264.00	PM-2A equipment	Skidllo boy
TAN607SR011/22/78830	TAN-607	PIT 15	13	1178	33.357	6810.00	Gradall frame	—
TAN607SR008/23/68800	TAN-607	PIT 9	14	1152	32.621	16344.00	PM-2A equipment	3 skids
TAN607SR006/24/65810	TAN-607	TRENCH 38	15	1080	30.582	2270.00	Metal tubing, plank, stainless steel	Dump truck
TAN607SR009/29/80150	TAN-607	PIT 15	16	1024	28.996	10896.00	Heavy metal beams, paper, wood, plastic.	—
TAN607SR012128173800	TAN-607	PIT 13	17	1000	28.317	1816.00	Backhoe	—
TANLPTSR011111176900	TAN-LPT	PIT 15	18	975	27.609	4086.00	112 reactor cavity, metal covers, tank cylinder	—
TAN607SR003/07/61800	TAN-607	PIT 3	19	900	25.485			Jet can
TAN607SR005/22/643	TAN-607	PIT 5	20	887	25.117	1362.00	Plywood box, stainless steel, champed iron, carbon steel	Plywood box
TAN607SR001/15/63820	TAN-607	TRENCH 28	21	810	22.937	1135.00	2 plywood box	Wooden box
TAN607SR001/22/63810	TAN-607	TRENCH 28	22	810	22.937	2724.00	Plywood boxes complete with rigging cables and bed	—
TAN607SR006/26/643	TAN-607	TRENCH 34	23	800	22.653	5448.00	ETR loop parts, 1 combustor section 5'×5' 10"	Box
TAN607SR004/13/666	TAN-607	PIT 5	24	800	22.653	363.20	SNAPTRAN 2-reactor frame	Dump/Atomic Energy Commission truck
TAN633SR005/02/661	TAN-633	TRENCH 41	25	800	22.653	8172.00	ML-1 reactor skid and shielding	Plastic wrap

Table 10. Heaviest 25 01s-listed shipments from TAN to the SDA, ranked by weight.

Document ID	Shipment From:	Shipment To:	Volume m^3	Rank	Tons	Weight Kilograms (kg)	Curies	Composition	Container Type
TAN633SR002/28/63810	TAN-633	PIT 4	70.35	1	38.0	34504.00	150.00	Mixed Fission Products from SL-1	Cask
TAN607SR010/29/69800	TAN-607	PIT 10	11.89	2	30.0	27240.00	1.55	Equipment: steel, alum, etc	Transp-trailer
TAN607SR007/09/62800	TAN-607	PIT 2	7.08	3	25.0	22700.00	4.00	Note: curies < 4 Turbo Generator (EROM SL-1)	G.E. Truck
TAN607SR011/09/71830	TAN-607	PIT 13	101.88	4	24.0	21792.00	*0.00*	Master boiler	
TAN607SR008/22/68810	TAN-607	PIT 9	62.54	5	21.0	19068.00	*0.00*	PM-2A equipment	Skid/lo boy
TAN607SR008/23/68810	TAN-607	PIT 9	40.64	6	21.0	19068.00	*0.00*	PM-2A equipment	2 skids
TAN607SR005/17/661	TAN-607	PIT 4	162.73	7	20.0	18160.00	*0.00*	Schedule 140 steel pipe, refueling support structure	Transportation/tractor trailer
TAN607SR008/24/71800	TAN-607	PIT 13	39.39	8	20.0	18160.00	0.00	Boiler and cooling tank	
TAN607SR008/23/68800	TAN-607	PIT 9	32.60	9	18.0	16344.00	0.00	PM-2A equipment	3 skids
TAN607SR007/06/71160	TAN-607	PIT 13	17.80	10	18.0	16344.00	0.55	Refueling tool	
TAN607SR008/26/68800	TAN-607	PIT 9	49.92	11	16.0	14528.00	0.00	PM-2A equipment	1 skids
TAN607SR008/20/68820	TAN-607	PIT 9	67.24	12	15.0	13620.00	0.00	PM-2A waste	2 metal containers
TAN607SR005/25/7715A	TAN-607	PIT 15	5.94	13	15.0	13620.00	1.00	Empty cask	
TAN633SR006/14/67800	TAN-633	PIT 6	10.19	14	14.0	12712.00	0.01	HETER shield and upper structure	Plastic wrap
TAN607SR011/23/66800	TAN-607	PIT 5	5.35	15	13.5	12258.00	0.00	Concrete	Truck
TAN607SR011/17/78845	TAN-607	PIT 15	13.73	16	12.3	11168.40	1.99	Misc. trash, Gradall counterweight	
TAN607SR009/30/71801	TAN-607	PIT 13	12.74	17	12.0	10896.00	27.50	PM-2A tank/contam boiler	
TAN607SR009/29/80150	TAN-607	PIT 15	28.98	18	12.0	10896.00	0.11	Heavy metal beams, paper, wood, plastic.	
TAN607SR004/23/65800	TAN-607	TRENCH 37	6.11	19	10.0	9080.00	0.02	1 metal, scrap waste that is irradiated and contaminated	Dumpster
TAN607SR005/18/70800	TAN-607	PIT 10	9.51	20	10.0	9080.00	*0.00*	Metal structure	Open/truck
TAN607SR005/19/70810	TAN-607	PIT 10	7.08	21	10.0	9080.00	*0.00*	Scrap steel	Dump truck
TAN607SR007/14/71120	TAN-607	PIT 13	18.11	22	10.0	9080.00	*0.00*	Boring mill	
TAN607SR012/19/72930	TAN-607	PIT 13	7.22	23	10.0	9080.00	151.30	Evaporator residue	
TAN607SR011/07/7413B	TAN-607	PIT 14	1.58	24	9.9	8943.80	0.10	Damaged casks and steel	
TAN607SR004/27/65800	TAN-607	TRENCH 37	6.11	25	9.0	8172.00	0.51	Scrap irradiated metal	Dumpster

Table 11. 01s-listed shipments containing lead.

Document ID	Shipment From:	Shipment To:	Volume m^3	Curies	Isotope	Weight kilograms (kg)	Composition	Container Type
TAN607SR010/28/60800	TAN-607	TRENCH 19	0.085	25.00	0	22.70	Irradiated Scrap Metal, Stainless	Lead Box
TAN607SR011/04/60800	TAN-607	TRENCH 20	0.764	25.00	0	22.70	Scrap Metal Wire	Lead Box
TAN607SR001/05/61800	TAN-607	TRENCH 20	0.057	3.00	0	34.05	Sealed Wooden Box inside Shielded Lead Cask	Lead Cask
TAN607SR001/18/61800	TAN-607	TRENCH 20	0.085	33.00	0	22.70	Scrap Metal	Lead Box
TAN607SR002/07/61810	TAN-607	TRENCH 20	0.057	7.00	0	34.05	Scrap Metal	Lead Cask
TAN607SR003/07/61810	TAN-607	TRENCH 20	0.071	10.00	0	22.70	Irradiated Scrap	Lead Box
TAN633SR002/07/61800	TAN-633	TRENCH 20	0.057	9.00	0	34.05	Scrap Metal	Lead Cask
TAN607SR007/19/62800	TAN-607	TRENCH 26	5.434	30.00	0	2724.00	Lead & Aluminum Suzie Shield Assemblies	Plastic
TAN607SR010/11/62800	TAN-607	PIT 2	2.264	0.02	0	454.00	Note: curies < .02 Stainless and Lead	
TAN607SR006/21/63810	TAN-607	TRENCH 30	5.660	0.03	0	681.00	216 ft^3 deleted from the weight column 13 Cardboard Boxes 2X2X3, 1 Fan, Light Bulbs, Lead Bricks Blocks	Dumpster
TAN607SR009/22/641	TAN-607	TRENCH 35	4.528	10.00	0	930.70	WCF Off-gas Filters and Misc. Lead and Stainless Steel	Plywood
TAN607SR006/23/65810	TAN-607	TRENCH 38	11.462	3.00	MFP	4540.00	Metal, Stainless, Lead	Dump Truck
TAN607SR006/24/65820	TAN-607	TRENCH 38	19.103	3.00	MFP	4540.00	Metal, Stainless, Lead	Dump Truck
TAN633SRO10/18/65800	TAN-633	TRENCH 40	0.085	166.00	0	90.80	General Hot Cells Trash including pieces of: 2ETR Poison Sections, GE Lead Experiments	Gallon Can

4. CALCULATION OF RADIONUCLIDE ACTIVITY

To support risk assessment for the SDA, radiological content data of waste shipments are broken down into activity levels of individual radionuclides important to the assessment. For wastes shipped from 1960 to 1970, the *Waste Disposal Request and Authorization* (waste shipment form) lists the originating organization, the composition of the waste (such as irradiated stainless steel), and its total curie content with no breakdown into individual radioisotopes.

For waste shipped from 1971 to 1983, the waste shipment form was changed to *Radioactive Waste Form*, which gives a description of the waste, total activity, and also a breakdown of the total activity into activities of individual radionuclides; however, the radionuclide breakdown seems to have been based on a few sets of formal isotopic ratios that contained certain irregularities that may not reflect the physical origins of the wastes. For example, the list of radionuclides includes Ni-59, which has a half-life of approximately 80,000 years—therefore, normally a relatively low activity—but does not include Ni-63, which has a half-life of approximately 100 years—therefore, normally a relatively high activity. In addition, it is hard to explain why the Ni-59 activity is often comparable to the activity of Co-60, which is often the dominant radioisotope in activated metal.

4.1 Overview of Methodology

For this reevaluation of the radiological content of the waste, the breakdown in radioisotopes on the *Radioactive Waste Form* was not used, but a uniform methodology has been applied to derive or rederive the breakdown of radiological contents for all shipments from 1960 to 1983. For waste shipped from 1984 to 1993, the only information available is the activities shipped per year; some records are broken down into activities of a few radionuclides and activities attributed to mixed fission or activation products. Information on composition of the waste is also incomplete, some indicating only that most of the waste was debris. For shipments during these years, we again apply a model to recalculate the activities of the radionuclides important to risk assessment.

Several pieces of information in the waste shipment forms help derive the isotopic breakdown: origin of the waste (e.g., GE-ANP referring to the General Electric Aircraft Nuclear Propulsion program), date of shipment, total curie content, and composition (e.g., metal or fuel specimen). The name of the program that generated the waste often identifies the reactor that was the originator, the listed composition gives some clue as to which reactor component gave rise to it, and the date of shipment gives a time frame following the end of reactor operation that can be used to make decay corrections for the radionuclide contents. The total curie content on the waste shipment forms serves as a normalization constant for the radionuclide breakdown.

The radioactive isotopic ratios are obtained from ORIGEN2 (Croft, 1980) calculations for the in-reactor irradiation of materials (generally 1 lb of material), based on the operating history of the reactor that is considered most probable to have produced the radioactive isotopes. The activities are decay-corrected to the date of shipment. The isotopic ratio is defined as the ratio of the activity of a specific isotope to the total activity in the irradiated material. The isotopic abundance of unirradiated material is taken from the *Chart of the Nuclides* (GE 1984).

To arrive at the activities of the individual isotopes, an ORIGEN2 model is identified for each shipment and the isotopic ratios of that model are applied to the total curie content for that shipment. Note that the radionuclides of interest do not include all radioisotopes in the irradiated material. For example, whenever an amount of waste contains Sr-90, it also contains an equal amount of activity of its short-lived daughter, Y-90; but Y-90 is not listed among the radionuclides of interest. Therefore, the sum of the activities of the individual radionuclides of concern is generally less than the total activity listed in the waste shipment forms. One exception to this method of breaking down radionuclides is the calculation for 1984 to 1993. For these years, the documented shipment of the total activities appears to have included only important radionuclides, e.g., Co-60 and Cs-137, and the total for a given year is often the sum of the radionuclides listed. Therefore, in the new calculation of the breakdown into individual radionuclides, the sum of the fractions of the important radionuclides is normalized to 1. The isotopic contents are calculated using spreadsheet programs.

4.2 Calculation Process and Description of Models

The process of calculating the isotopic contents in a waste shipment starts with identifying the origin from information in the waste shipment forms. Then a model is constructed for the generation of the isotopes from in-reactor irradiation. The model includes the reactor type (e.g., fast or thermal), fuel and fuel cladding composition, irradiation time, and decay time since end of irradiation. The model parameters are used as input parameters to ORIGEN2 calculations. The type of reactor determines which set of neutron cross-sections to use in the calculations. The cross-section libraries used are those that come with the ORIGEN2 code.

The output of the ORIGEN2 calculations includes activities of radionuclides separated into three groups:

- Activation products (e.g., Co-60, Ni-59)
- Actinides (e.g., Pu-239, Am-241)
- Fission products (e.g., Cs-137, Sr-90).

The activity ratio of the individual radionuclides to the total activity in the irradiated mass are applied to the total activity in the waste shipment to arrive at the activities of the individual radionuclides in the waste shipment. Exceptions to this ratio determination are those for the mixed fission product (MFP) model, and the post-1983 (POST83) radionuclide model. For the MFP model, ORIGEN2 calculates irradiated fuel with cladding. Since the waste is identified as containing mixed fission products—also presumably fuel since no reprocessing occurred—but not activation products, the isotopic ratios are calculated based on total curie contents of fission products and actinides only. For the POST83 model, the sum of the ratios of the important radionuclides is normalized to 1. For each shipment year, the activities are decayed from the shipment date to December 31 of that year.

For shipments from 1960 to 1993, 18 models are constructed to arrive at 18 sets of isotopic ratios. These models are described below.

4.2.1 SS3

The SS3 model gives the isotopic ratios for stainless steel three years (hence the “3” in SS3) after being irradiated at 1.0×10^{14} neutron/cm^2-s for 1,200 hours. The neutron flux is typical of the one-group ORIGEN2 neutron flux for a light water reactor. The cross-section set used in the calculations is the ORIGEN2 boiling water reactor cross-section library (ORIGEN2, 1980, bwru.lib). The irradiation time is considered to be typical of the total operating times for test reactors; the decay time is considered to be typical of the interval between final shutdown of the reactor and disposal of reactor components.

A generic composition of major constituents of the stainless steel is used. In weight percent, the composition is: C, 0.12; Mn, 2.00; Si, 1.00; Cr, 20.00; Ni, 15.00; Mo, 1.00; Fe, 60.65 (Baumeister 1967). To maximize the production of Co-60, a 0.20% cobalt impurity—higher than normally found in stainless steel (0.1 to 0.15%)—is included in the composition. Similarly, in order to estimate the risk-important radionuclide, C1-36, a 70 pprn chlorine impurity is also included in the composition (Evans 1984).

4.2.2 HTRE4

The HTRE4 model simulates the operation of the HTRE-1 reactor (Loftness 1964a) followed by four years (hence the "4" in HTRE4) of decay. The operating time used was 100 hours at 17.5 MW (thermal), corresponding to a neutron flux of 1.04 x 10^{14} neutrons/cm^2-s. The reactor model consists of 44 kg of 93.4% enriched uranium (in oxide form) and 1,232.5 kg of Ni-Cr alloy (clad and structural material, 20% chromium, 80% nickel), including 2.5 kg of cobalt impurity. A 10 pprn chlorine impurity is assumed for the Ni-based alloys (Carboneau 2002). The U-234 content in the uranium is assumed to be 1% of the U-235 in the uranium. The cross-section set used is the bwru.lib.

4.2.3 Inconel

The Inconel composition is assumed to be generic with the following elemental weight contents: Ni, 75%; Cr, 15%; Fe, 9.8%, and (enhanced) Co, 0.2% (Baumeister 1967). A 10 pprn chlorine impurity is also included to estimate the production of Cl-36. This model is intended to simulate the HTRE-3 reactor vessel (Loftness 1964b). It is irradiated at 5 x 10^{13} neutron/cm^2-s (neutron flux just outside the reactor core) for 160 hours and decayed for 30 days. The cross-section set used is the bwru.lib.

4.2.4 ETRSpec

This model simulates the irradiation of a fuel specimen in the Engineering Test Reactor (ASME 1959; AEC 1957). The fuel is assumed to be UO_2, clad in generic stainless steel. The uranium is 50% enriched in U-235 and the U-234 content is 1% of U-235. The stainless steel includes 0.2% cobalt and 70 pprn chlorine. The fuel-to-clad ratio, by weight, is 7:3. The fuel is irradiated for 15 days at a neutron flux level of 1.6 x 10^{14} neutrons/cm^2-s, equivalent to a burnup of 1%. The cross-section set used is the ORIGEN2 pressurized water reactor library (pwru.lib).

4.2.5 SLIEB

This model computes the radionuclide contents in the endboxes of the SL-1 reactor core (Loftness 1964c). The endboxes were made of aluminum with approximately 1% nickel. For a conservative estimate of Co-60, a 0.002% (0.2% of the nickel content) impurity of cobalt is included in the composition. The endboxes are irradiated for 10,000 hours at 5 x 10^{13} neutron/cm^2-s. At the end of this steady state irradiation, the neutron flux is increased a thousand fold for five seconds to simulate the accident that destroyed the SL-1 reactor core. The decay time between the end of irradiation and the waste shipment date is set at 630 days. The cross-section set used is the boiling water reactor cross-section library (ORIGEN2, 1980, bwru.lib).

4.2.6 MFP

The mixed fission products (MFP) model determines the source term for waste arising from irradiated fuel examination. The fuel is assumed to be typical light water reactor fuel (UO_2) with 5% U-235 enrichment. The fuel cladding is assumed to be stainless steel, but in calculating the isotopic ratios, radionuclides in the cladding are ignored. Actinides in the fuel, however, are included with the fission products based on the assumption that fission products were not separated from the fuel when the fuel was examined destructively. The fuel is irradiated for 200 days at a neutron flux of 3 x 10^{14} neutron/cm^2-s and decayed for three years. The cross-section library used is the pressurized water reactor cross-section library (ORIGEN2, 1980, pwru.lib).

4.2.7 HTRE5

This model is the same as the HTRE4 model, except the decay time is five years.

4.2.8 MLlsh

The MLlsh model calculates the radioisotope contents in the lead-tungsten shield of the ML-1 reactor (Loftness 1964d). The shield is assumed to be 50% lead and 50% tungsten by weight. The shield is irradiated for 1,000 hours at a neutron flux of 1×10^{13} neutrons/cm^2-s and the decay time is assumed to be 660 days. The cross-section library used is the boiling water reactor cross-section library (bwru.lib). This model produces no radionuclide important to risk assessment.

4.2.9 EBRI

The EBRI model simulates an average composition of the EBR-I reactor core (Loftness 1964e). The fuel composition is assumed to be uranium enriched to *5%* in U-235. The cladding is assumed to be stainless steel (90%) and zirconium (10%). The stainless steel is assumed to contain 0.2% cobalt and 70 pprn chlorine. **A** fuel element is assumed to be 70% fuel and 30% cladding by mass. The fuel element is irradiated at a fast neutron flux of 1.7×10^{15} neutrons/cm^2-s for 300 days and decayed for 4.5 years. The cross-section set used is the fast flux cross-section library (ORIGEN2, 1980, fftfc.lib), for the Fast Flux Test Facility.

4.2.10 EBRIISS

The EBRIISS model simulates the irradiation of stainless steel in the EBR-II reactor (Loftness 1964f). The stainless steel has a generic composition as described under the SS3 model, with 0.2% cobalt and 70 pprn chlorine impurities. The steel is irradiated for 300 days at a neutron flux of 1.7×10^{15} fast neutrons/cm^2-s and decayed for three years. The cross-section library used is the fast flux cross-section library (ORIGEN2, 1980, fftfc.lib).

4.2.11 HTRE8

The HTRE8 model is the same as the HTRE4 model for the HTRE reactors except the decay time is eight years instead of four.

4.2.12 EBRII

The EBRII model simulates the irradiation of an EBR-II fuel element. The fuel element is assumed to be made of metallic uranium, enriched to 50% in U-235, with 0.5% of U-234, and enclosed in a stainless steel cladding. The fuel-to-cladding mass ratio is assumed to be 7:3. The stainless steel has generic composition with 0.2% cobalt and 70 pprn chlorine impurities. The fuel element is irradiated for 300 days at 1.7×10^{15} fast neutrons/cm^2-s and decayed for three years. The cross-section library is the fast flux cross-section library (ORIGEN2, 1980, fftfc.lib).

4.2.13 HTRE3

The HTRE3 model is the same as the HTRE4 model, except that the decay time is three years instead of four.

4.2.14 Generic

The Generic model applies to waste generated from routine hot cell/shop examination of irradiated fuel. It simulates UO_2 enriched to 50% in U-235, clad in stainless steel, and irradiated in a light water reactor for 100 days and decayed for three years. The stainless steel has generic composition and contains

0.2% cobalt and 70 pprn chlorine impurities. The irradiation flux is 1.6 x 10^{14} neutrons/cm^2-s. The cross-section library used is the pressurized water reactor cross-section library (ORIGEN2, 1980, pwru.lib).

4.2.15 SPM2A

The SPM2A model provides the isotopic composition of the reactor vessel of the PM-2A reactor (S-PM-2A waste) (Loftness 1964g; Mousseau 1967). The reactor vessel was made of carbon steel clad in stainless steel. The model assumes that the material is 85% carbon steel and 15% stainless steel. The carbon content in carbon steel is assumed to be 0.5% and the composition of the stainless steel is assumed to be generic with 0.2% cobalt and 70 pprn chlorine impurities. The steel is irradiated for three years at a neutron flux of 1 x 10^{12} neutrons/cm^2-s and decayed for 13 years. The cross-section library used is the pressurized water reactor cross-section library (ORIGEN2, 1980, pwru.lib).

4.2.16 SPM2ASS

SPM2ASS is the model for irradiation of stainless steel in the PM-2A reactor. The stainless steel has generic composition with 0.2% cobalt and 70 pprn chlorine impurities. The steel is irradiated at a neutron flux of 1 x 10^{12} neutrons/cm^2-s for three years and decayed for 13 years. The cross-section set used is the pressurized water reactor library (ORIGEN2, 1980, pwru.lib).

4.2.17 PM2ASS3

The PM2ASS3 model is similar to the SPM2ASS3 model, except that the decay time is three years instead of 13 years. This model applies to the stainless steel waste shipped three years after the end of the PM-2A reactor operation.

4.2.18 POST83

The POST83 model gives the isotopic ratios of the important radionuclides for waste shipped from 1984 to 1993. The sum of these ratios is normalized to 1, so that other radionuclides are not included in the total reported activities. The model composition is a mixture of fuel and structural materials. The fuel is assumed to be UO_2, enriched to 10% in U-235, and 0.1% in U-234. The structural materials consist of 2/3 stainless steel and 1/3 Inconel. Both the stainless steel and the Inconel contain 0.2% cobalt. In addition, the stainless steel contains 70 pprn chlorine and the Inconel 10 pprn chlorine. The fuel comprises 70% of the total mass and the structural material 30% of the total mass. The composite material is irradiated for 100 hours at a neutron flux of 1.6 x 10^{14} neutrons/cm^2-s and decayed for three years.

4.3 Disposal Waste Stream and Model Relationship

An isotopic model was identified for each waste stream shipped in a particular year, based on available information about the origin of the waste linking it to a reactor and the material making up the waste. When such information was not available, educated judgment assigned a model to the waste based on information from Hot Shop operations and programmatic research during the time the waste was shipped. Table 12 shows the shipment identification and the model applied to the shipment for the calculation of radioisotope breakdowns. The model names correspond to the names described in Section 4.2. The type of waste is divided into two categories: metal and debris. For risk assessment purposes, it may be assumed that the metal waste matrix provides an initial barrier to radioisotope migration until the matrix is corroded, but that the debris waste matrix provides no barrier to radioisotope migration. The descriptions of the material in the shipments are based on information in the shipment papers.

Table 12. Waste shipment description and corresponding model for its isotopic ratios.

Year	Waste stream	Shipment No.	Date	Matrix type	Material	Model
1960	TAN-607-2	TAN607SR002/01/60800	2/1/60	Metal	SS (stainless steel)	ss3
1960	TAN-607-2	TAN607SR002/05/60800	2/5/60	Metal	SS	ss3
1960	TAN-633-2	TAN633SR008/16/60800	8/16/60	Metal	Metal	ss3
1960	TAN-607-2	TAN607SR009/13/60800	9/13/60	Debris	FP (fission product)	HTRE4
1960	TAN-607-2	TAN607SR006/10/60800	6/10/60	Metal	SS	ss3
1960	TAN-607-2	TAN607SR007/20/60800	7/20/60	Debris	FP	HTRE4
1960	TAN-607-2	TAN607SR009/13/60810	9/13/60	Debris	FP	HTRE4
1960	TAN-607-2	TAN607SR007/22/60800	7/22/60	Metal	Metal	ss3
1960	TAN-607-2	TAN607SR007/11/60800	7/11/60	Metal	Metal	ss3
1961	TAN-607-2	TAN607SR001/18/61800	1/18/61	Metal	Scrap metal	Inconel
1961	TAN-607-2	TAN607SR002/07/61810	2/7/61	Metal	Scrap metal	Inconel
1961	TAN-633-2	TAN633SR002/07/61800	2/7/61	Metal	Scrap metal	Inconel
1961	TAN-607-2	TAN607SR002/15/61800	2/15/61	Metal	Scrap metal	Inconel
1961	TAN-607-2	TAN607SR002/15/61810	2/15/61	Metal	Scrap metal	Inconel
1961	TAN-607-2	TAN607SR003/07/61800	3/7/61	Metal	—	Inconel
1961	TAN-607-2	TAN607SR003/07/61810	3/7/61	Metal	Irradiated scrap	Inconel
1961	TAN-607-2	TAN607SR008/04/61810	8/4/61	Metal	Scrap metal	Inconel
1961	TAN-607-2	TAN607SR008/11/61800	8/11/61	Metal	Scrap metal	Inconel
1961	TAN-607-2	TAN607SR008/21/61800	8/21/61	Metal	Scrap	Inconel
1961	TAN-607-2	TAN607SR010/23/61800	10/23/61	Metal	Scrap metal	Inconel
1962	TAN-607-3	TAN607SR005/21/62800	5/21/62	Metal	ETR test specimen	ETRspec
1962	TAN-607-3	TAN607SR007/02/62800	7/2/62	Metal	Irradiated sample	ETRspec
1962	TAN-607-3	TAN607SR007/06/62800	7/6/62	Metal	Scrap metal, fuel	ETRspec
1962	TAN-607-3	TAN607SR010/23/62810	10/23/62	Metal	SL-1 endbox	SL1EB
1962	TAN-607-3	TAN607SR010/25/62800	10/25/62	Metal	SL-1 endbox	SL1EB
1963	TAN-607-3	TAN607SR001/30/63810	1/30/63	Debris	Rad waste	MFP
1963	TAN-633-3	TAN633SR001/29/63810	1/29/63	Debris	Rad waste	MFP
1963	TAN-633-3	TAN633SR002/28/63810	2/28/63	Debris	Mixed fp	MFP
1963	TAN-633-3	TAN633SR005/15/63810	5/15/63	Debris	Scrap	MFP
1963	TAN-633-3	TAN633SR009/10/63800	9/10/63	Debris	Scrap	MFP
1963	TAN-633-3	TAN633SR009/13/63810	9/13/63	Debris	Scrap	MFP
1963	TAN-633-3	TAN633SR009/12/63810	9/12/63	Debris	Scrap	MFP
1964	TAN-633-4	TAN633SR001/07/641	1/7/64	Metal	Scrap metal	ss3
1964	TAN-633-4	TAN633SR006/17/641	6/17/64	Debris	Hot trash	MFP
1964	TAN-633-4	TAN633SR007/02/641	7/2/64	Debris	Off-gas filters	MFP
1964	TAN-633-4	TAN633SR007/10/641	7/10/64	Debris	Off-gas filters	MFP
1964	TAN-633-4	TAN633SR010/23/641	10/23/64	Metal	Hot cell and GE scrap	HTRE3
1964	TAN-633-4	TAN633SR012/30/64830	12/30/64	Debris	Hot cell trash	MFP
1965	TAN-633-4	TAN633SR003/11/65800	3/11/65	Metal	GE, hot cell trash	HTRE3
1965	TAN-633-4	TAN633SR005/14/65800	5/14/65	Metal	EBR II, hot cell trash	HTRE3
1965	TAN-633-4	TAN633SR006/04/65800	6/4/65	Metal	SS u02	ETRspec
1965	TAN-633-4	TAN633SR006/17/65810	6/17/65	Metal	GE trash	HTRE3
1965	TAN-633-4	TAN633SR010/18/65800	10/18/65	Metal	GE trash, ETR poison	HTRE3
1965	TAN-633-4	TAN633SR010/19/65800	10/19/65	Metal	GE trash	HTRE3

Table 12. (continued).

Year	Waste stream	Shipment No.	Date	Matrix type	Material	Model
1966	TAN-633-4	TAN633SR003/18/661	3/18/66	Metal	ML-1 reflector	ML1sh
1966	TAN-633-4	TAN633SR003/18/662	3/18/66	Metal	ML-1 reflector	ML1sh
1966	TAN-633-4	TAN633SR003/18/663	3/18/66	Metal	ML-1 reflector	ML1sh
1966	TAN-633-4	TAN633SR003/18/664	3/18/66	Metal	GE trash	HTRE5
1966	TAN-633-4	TAN633SR010/05/662	10/5/66	Metal	HETER control rod tip	553
1966	TAN-633-4	TAN633SR011/10/66820	11/10/66	Metal	HETER control rod tip	553
1967	TAN-633-5	TAN633SR003/10/67800	3/10/67	Metal	EBR II pin clad	EBRIISS
1967	TAN-633-5	TAN633SR004/07/67800	4/7/67	Metal	GE trash	HTRE5
1967	TAN-633-5	TAN633SR006/01/67800	6/1/67	Metal	PM-2A SS	PM2ASS3
1967	TAN-633-5	TAN633SR008/07/67800	8/7/67	Metal	PM-2A SS	PM2ASS3
1967	TAN-633-5	TAN633SR008/07/67810	8/7/67	Metal	PM-2A SS	PM2ASS3
1967	TAN-633-5	TAN633SR008/07/67820	8/7/67	Metal	ORNL scrap, SS	553
1967	TAN-633-5	TAN633SR008/15/67800	8/15/67	Metal	PM-2A SS	PM2ASS3
1967	TAN-633-5	TAN633SR008/18/67800	8/18/67	Metal	Hot cell trash	HTRE5
1967	TAN-633-5	TAN633SR009/15/67800	9/15/67	Metal	ML-1 hardware	553
1967	TAN-633-5	TAN633SR010/17/67820	10/17/67	Metal	Hot cell trash	HTRE5
1968	TAN-633-5	TAN633SR005/31/68800	5/31/68	Metal	SS scrap	553
1968	TAN-633-5	TAN633SR007/01/68800	7/1/68	Metal	EBR I pin tip, U-235	EBRI
1968	TAN-633-5	TAN633SR008/22/68800	8/22/68	Metal	Metal scrap	553
1968	TAN-633-5	TAN633SR010/17/68800	10/17/68	Metal	Metal trash	553
1969	TAN-633-5	TAN633SR001/20/69800	1/20/69	Metal	GE trash	HTRE8
1969	TAN-633-5	TAN633SR002/12/69800	2/12/69	Metal	EBRII control rod	EBRII
1969	TAN-633-5	TAN633SR005/07/69830	5/7/69	Metal	ML-1 SS	553
1969	TAN-633-5	TAN633SR005/15/69800	5/15/69	Metal	GE trash	HTRE8
1969	TAN-633-5	TAN633SR007/24/69810	7/24/69	Metal	GE trash, EBRII clad	HTRE8
1969	TAN-633-5	TAN633SR010/03/69800	10/3/69	Metal	GE trash	HTRE8
1970	TAN-633-5	TAN633SR002/12/70800	2/12/70	Metal	Experiment trash, SS	553
1970	TAN-633-5	TAN633SR004/17/70800	4/17/70	Metal	Misc trash	Generic
1970	TAN-607-5	TAN607SR006/18/70800	6/18/70	Metal	Misc trash	Generic
1970	TAN-607-5	TAN607SR010/02/70830	10/2/70	Metal	Experiment trash, SS	553
1971	TAN-607-5	TAN607SR006/15/711330	6/15/71	Metal	Hot cell scrap	Generic
1971	TAN-607-5	TAN607SR012/01/711300	12/1/71	Metal	Hot cell scrap	Generic
1972	TAN-607-5	TAN607SR009/11/72930	9/11/72	Metal	Hot cell scrap	Generic
1972	TAN-607-5	TAN607SR012/19/72930	12/19/72	Debris	Evap residue	MFP
1973	TAN-607-5	TAN607SR001/22/731235	1/22/73	Metal	Hot cell scrap	Generic
1973	TAN-607-5	TAN607SR007/27/73901	7/27/73	Metal	Stainless steel	553
1974	TAN-607-5	TAN607SR004/02/74900	4/2/74	Metal	Stainless steel	553
1974	TAN-607-5	TAN607SR004/10/74900	4/10/74	Metal	Stainless steel	553
1974	TAN-607-5	TAN607SR007/03/741000	7/3/74	Metal	Stainless steel	553
1974	TAN-607-5	TAN607SR007/03/741001	7/3/74	Metal	Stainless steel	553
1974	TAN-607-5	TAN607SR007/30/741000	7/30/74	Metal	Metal scrap	553
1975	TAN-607-5	TAN607SR010/31/751000	10/31/75	Metal	Hot cell sweep	Generic
1976	TAN-607-5	TAN607SR007/02/76900	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/13/76104	5/13/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/13/76120	5/13/76	Metal	S-PM2A	SPM2A

Table 12. (continued).

Year	Waste stream	Shipment No.	Date	Matrix type	Material	Model
1976	TAN-607-5	TAN607SR005/13/76110	5/13/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/13/76111	5/13/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/28/76830	6/28/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/76900	6/30/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76800	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/76800	6/30/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/76930	6/30/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76100	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76110	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76113	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76130	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76133	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76140	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76830	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76930	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614A	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614B	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614C	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614D	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614E	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614F	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7614G	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/76154	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615A	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615C	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615E	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615G	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615H	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/10/76815	6/10/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/27/76130	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/27/76830	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/28/76103	6/28/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/28/76800	6/28/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/23/76103	7/23/76	Metal	Non comb waste	SPM2ASS
1976	TAN-607-5	TAN607SR006/10/76905	6/10/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/27/76110	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/27/7611A	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/27/76940	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/76100	6/30/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/76110	6/30/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/7614A	6/30/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR007/02/76809	7/2/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615B	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR005/07/7615D	5/7/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/10/76800	6/10/76	Metal	S-PM2A	SPM2A

Table 12. (continued).

Year	Waste stream	Shipment No.	Date	Matrix type	Material	Model
1976	TAN-607-5	TAN607SR006/27/76113	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/27/76900	6/27/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/28/76930	6/28/76	Metal	S-PM2A	SPM2A
1976	TAN-607-5	TAN607SR006/30/76130	6/30/76	Metal	S-PM2A	SPM2A
1977	TAN-607-5	TAN607SR002/17/77140	2/24/77	Metal	Stainless steel	ss3
1977	TAN-607-5	TAN607SR003/15/77130	3/16/77	Metal	Stainless steel	ss3
1978	TAN-607-5	TAN607SR001/16/7810A	1/16/78	Metal	Stainless steel	ss3
1978	TAN-607-5	TAN607SR004/19/7812A	4/19/78	Metal	Stainless steel	ss3
1979	TAN-607-5	TAN607SR011/07/79100	11/7/79	Metal	Misc hot shop	Generic
1979	TAN-607-5	TAN607SR001/25/79900	1/25/79	Metal	Gravel, hot shop scrap	Generic
1979	TAN-607-5	TAN607SR010/30/79140	10/30/79	Metal	Misc hot shop	Generic
1979	TAN-607-5	TAN607SR009/27/79900	9/27/79	Metal	Misc hot shop	Generic
1979	TAN-607-5	TAN607SR011/02/79900	11/2/79	Metal	Misc hot shop	Generic
1979	TAN-607-5	TAN607SR003/05/79100	3/5/79	Metal	Plastic, paper, metal	Generic
1979	TAN-607-5	TAN607SR010/31/79153	10/31/79	Metal	Misc hot shop	Generic
1979	TAN-607-5	TAN607SR007/11/79140	7/11/79	Metal	Misc hot shop	Generic
1980	TAN-607-5	TAN607SR009/22/80100	9/22/80	Debris	PBF resin	MFP
1980	TAN-607-5	TAN607SR010/07/8012B	10/7/80	Debris	PBF resin	MFP
1981	TAN-607-5	TAN607SR009/02/81100	9/2/81	Debris	Concrete plug	MFP
1981	TAN-607-5	TAN607SR005/27/81100	5/27/81	Metal	Non comb waste	ss3
1982	TAN-607-5	TAN607SR003/11/82853	3/11/82	Metal	Misc hot shop	Generic
1982	TAN-607-5	TAN607SR003/12/82112	3/12/82	Metal	Misc hot shop	Generic
1982	TAN-607-5	TAN607SR006/02/82103	6/2/82	Metal	Non comb waste	ss3
1983	TAN-607-5	TAN607SR007/11/83900	7/11/83	Debris	Resin	MFP
1984	TAN-607-6R	—	6/30/94	Debris	—	POST83
1985	TAN-607-6R	—	6/30/94	Debris	—	POST83
1986	TAN-607-6R	—	6/30/94	Debris	—	POST83
1987	TAN-607-6R	—	6/30/94	Debris	—	POST83
1988	TAN-607-6R	—	6/30/94	Debris	—	POST83
1989	TAN-607-6R	—	6/30/94	Debris	—	POST83
1990	TAN-607-6R	—	6/30/94	Debris	—	POST83
1991	TAN-607-6R	—	6/30/94	Debris	—	POST83
1992	TAN-607-6R	—	6/30/94	Debris	—	POST83
1993	TAN-607-6R	—	6/30/94	Debris	—	POST83

4.4 Model-Derived Isotopic Ratios

The isotopic ratios of the various models are listed in Table 13. The ratios generally refer to the ratios of the activities of the isotopes important to risk assessment to the total activity calculated for the models, including the activities of the decay daughters of the isotopes and other isotopes not listed in this table. The sum of the ratios, therefore, generally does not add to unity. One exception is the POST83 model ratios, whose sum is normalized to unity. If a model is limited to a certain category of radionuclides, e.g., fission products, the total activity is the total activity of all the fission products, but does not include the activities of actinides and activation products.

Table 13. Ratios of isotopic activities to total activity for the waste models.

Isotope	ss3	HTRE4	Inconel	ETRspec	SL1EB	MFP	HTRE5
H 3	0.000E+00	3.734E-04	0.000E+00	3.350E-04	0.000E+00	3.988E-04	4.470E-04
Be 10	1.103E-11	0.000E+00	0.000E+00	1.499E-13	0.000E+00	0.000E+00	0.000E+00
C 14	5.469E-10	3.425E-09	0.000E+00	5.218E-09	0.000E+00	1.119E-10	4.392E-09
C136	4.201E-07	2.117E-08	1.677E-09	4.222E-09	0.000E+00	0.000E+00	2.713E-08
Co 60	4.540E-01	1.447E-01	1.890E-02	4.581E-03	6.686E-01	0.000E+00	1.615E-01
Ni 59	2.029E-04	3.814E-04	2.839E-05	2.312E-06	1.763E-03	0.000E+00	4.881E-04
Ni 63	2.782E-02	5.186E-02	3.975E-03	2.796E-04	2.447E-01	0.000E+00	6.594E-02
Sr 90	0.000E+00	9.387E-02	0.000E+00	8.127E-02	0.000E+00	8.365E-02	1.163E-01
Nb 94	1.943E-09	2.254E-11	0.000E+00	4.541E-11	0.000E+00	5.059E-11	2.860E-11
Tc 99	3.456E-07	1.477E-05	0.000E+00	1.288E-05	0.000E+00	1.360E-05	1.919E-05
I129	0.000E+00	2.476E-08	0.000E+00	2.038E-08	0.000E+00	2.524E-08	3.025E-08
Cs137	0.000E+00	9.760E-02	0.000E+00	8.454E-02	0.000E+00	9.335E-02	1.209E-01
Eu152	0.000E+00	2.365E-08	0.000E+00	1.630E-07	0.000E+00	5.640E-06	7.333E-07
Eu154	0.000E+00	3.702E-06	0.000E+00	3.495E-05	0.000E+00	1.543E-03	1.042E-04
Pb210	0.000E+00	1.554E-12	0.000E+00	1.039E-13	0.000E+00	0.000E+00	4.069E-13
Ra226	0.000E+00	3.876E-11	0.000E+00	3.395E-12	0.000E+00	1.884E-13	8.025E-12
Ra228	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ac227	0.000E+00	2.078E-10	0.000E+00	1.968E-11	0.000E+00	1.376E-12	4.214E-11
Th228	0.000E+00	1.215E-09	0.000E+00	1.180E-09	0.000E+00	2.166E-09	1.743E-09
Th229	0.000E+00	0.000E+00	0.000E+00	9.656E-15	0.000E+00	0.000E+00	1.816E-14
Th230	0.000E+00	4.464E-08	0.000E+00	5.156E-09	0.000E+00	2.455E-10	7.246E-09
Th232	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pa231	0.000E+00	3.387E-09	0.000E+00	4.181E-10	0.000E+00	2.146E-11	5.444E-10
U232	0.000E+00	1.563E-09	0.000E+00	1.752E-09	0.000E+00	3.604E-09	2.041E-09
U233	0.000E+00	2.810E-11	0.000E+00	3.255E-11	0.000E+00	3.067E-11	3.567E-11
U234	0.000E+00	1.236E-03	0.000E+00	1.884E-04	0.000E+00	7.700E-06	1.574E-04
U235	0.000E+00	3.979E-05	0.000E+00	6.466E-06	0.000E+00	2.193E-07	5.000E-06
U236	0.000E+00	5.024E-07	0.000E+00	4.237E-07	0.000E+00	4.071E-07	6.369E-07
U238	0.000E+00	4.387E-07	0.000E+00	1.007E-06	0.000E+00	8.652E-07	5.625E-08
Np237	0.000E+00	9.872E-10	0.000E+00	6.023E-09	0.000E+00	1.343E-07	1.093E-08
Pu238	0.000E+00	1.110E-09	0.000E+00	1.252E-07	0.000E+00	1.849E-04	6.052E-07
Pu239	0.000E+00	2.799E-06	0.000E+00	3.458E-05	0.000E+00	5.099E-04	3.493E-06
Pu240	0.000E+00	5.712E-09	0.000E+00	5.647E-07	0.000E+00	2.675E-04	1.336E-07
Pu241	0.000E+00	2.629E-09	0.000E+00	1.442E-06	0.000E+00	1.713E-02	6.231E-07
Pu242	0.000E+00	0.000E+00	0.000E+00	1.153E-13	0.000E+00	3.978E-08	1.101E-13
Pu244	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Am241	0.000E+00	1.855E-11	0.000E+00	7.472E-09	0.000E+00	9.265E-05	5.661E-09
Am243	0.000E+00	0.000E+00	0.000E+00	7.909E-15	0.000E+00	7.117E-08	1.403E-14
Cm243	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.617E-08	0.000E+00
Cm244	0.000E+00	0.000E+00	0.000E+00	4.382E-15	0.000E+00	1.156E-06	1.437E-14
Cm245	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.601E-11	0.000E+00
Cm246	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.218E-13	0.000E+00
Cm247	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm248	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 13. (continued).

Isotope	ML 1sh	EBRI	EBRIISS	HTRE8	EBRII	HTRE3	Generic
H 3	0.000E+00	1.046E-03	5.102E-09	5.327E-04	7.026E-04	2.854E-04	3.529E-04
Be 10	0.000E+00	1.931E-11	3.471E-10	0.000E+00	2.393E-12	0.000E+00	1.673E-13
C 14	0.000E+00	2.043E-10	3.625E-10	6.192E-09	1.212E-10	2.507E-09	5.704E-09
C136	0.000E+00	5.461E-09	9.818E-08	3.827E-08	6.770E-10	1.548E-08	4.607E-09
Co 60	0.000E+00	1.639E-02	3.589E-01	1.535E-01	2.474E-03	1.199E-01	4.923E-03
Ni 59	0.000E+00	3.088E-06	5.552E-05	6.885E-04	3.827E-07	2.786E-04	2.510E-06
Ni 63	0.000E+00	4.226E-04	7.678E-03	9.097E-02	5.294E-05	3.823E-02	3.051E-04
Sr 90	0.000E+00	1.075E-01	0.000E+00	1.527E-01	8.798E-02	6.957E-02	8.582E-02
Nb 94	0.000E+00	3.468E-09	6.095E-08	4.034E-11	4.398E-10	1.632E-11	4.934E-11
Tc 99	0.000E+00	2.178E-05	1.071E-06	2.707E-05	1.381E-05	1.095E-05	1.333E-05
I129	0.000E+00	6.803E-08	0.000E+00	4.266E-08	3.740E-08	1.726E-08	2.149E-08
Cs137	0.000E+00	1.405E-01	0.000E+00	1.592E-01	9.593E-02	7.230E-02	8.933E-02
Eu152	0.000E+00	3.436E-06	0.000E+00	8.878E-07	1.823E-06	4.633E-07	2.834E-06
Eu154	0.000E+00	6.609E-04	0.000E+00	1.154E-04	3.502E-04	6.987E-05	3.415E-04
Pb210	0.000E+00	8.271E-14	0.000E+00	2.243E-12	4.109E-14	5.311E-14	2.078E-14
Ra226	0.000E+00	1.369E-12	0.000E+00	2.847E-11	7.886E-13	1.698E-12	6.310E-13
Ra228	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ac227	0.000E+00	7.466E-12	0.000E+00	1.447E-10	4.396E-12	9.173E-12	3.741E-12
Th228	0.000E+00	5.069E-08	0.000E+00	2.705E-09	1.736E-08	8.037E-10	1.403E-09
Th229	0.000E+00	4.785E-13	0.000E+00	3.989E-14	4.140E-13	6.526E-15	1.304E-14
Th230	0.000E+00	1.186E-09	0.000E+00	1.622E-08	9.509E-10	2.518E-09	8.901E-10
Th232	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pa231	0.000E+00	9.215E-11	0.000E+00	1.215E-09	7.429E-11	1.900E-10	7.176E-11
U232	0.000E+00	7.703E-08	0.000E+00	2.798E-09	2.619E-08	1.187E-09	2.065E-09
U233	0.000E+00	7.432E-10	0.000E+00	5.051E-11	8.134E-10	2.030E-11	3.394E-11
U234	0.000E+00	2.472E-05	0.000E+00	2.221E-04	2.757E-05	8.985E-05	3.021E-05
U235	0.000E+00	8.054E-07	0.000E+00	7.052E-06	8.983E-07	2.853E-06	9.923E-07
U236	0.000E+00	4.994E-07	0.000E+00	8.983E-07	5.564E-07	3.635E-07	4.465E-07
U238	0.000E+00	2.576E-06	0.000E+00	7.934E-08	1.498E-07	3.21OE-08	1.651E-07
Np237	0.000E+00	6.854E-07	0.000E+00	1.542E-08	9.875E-08	6.239E-09	2.799E-08
Pu238	0.000E+00	4.076E-04	0.000E+00	8.341E-07	4.690E-05	3.510E-07	8.014E-06
Pu239	0.000E+00	5.969E-03	0.000E+00	4.926E-06	3.470E-04	1.994E-06	3.441E-05
Pu240	0.000E+00	1.916E-04	0.000E+00	1.885E-07	1.114E-05	7.629E-08	4.862E-06
Pu241	0.000E+00	4.522E-04	0.000E+00	7.609E-07	2.826E-05	3.918E-07	8.741E-05
Pu242	0.000E+00	8.830E-11	0.000E+00	1.553E-13	5.133E-12	6.282E-14	5.011E-11
Pu244	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Am241	0.000E+00	3.815E-06	0.000E+00	1.187E-08	1.567E-07	2.042E-09	4.621E-07
Am243	0.000E+00	1.557E-11	0.000E+00	1.978E-14	9.052E-13	8.007E-15	2.291E-11
Cm243	0.000E+00	3.132E-11	0.000E+00	0.000E+00	1.888E-12	0.000E+00	4.490E-12
Cm244	0.000E+00	3.225E-11	0.000E+00	1.806E-14	1.985E-12	8.850E-15	9.345E-11
Cm245	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm246	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm247	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm248	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 13. (continued).

Isotope	SPM2A	SPM2ASS	PM2ASS3	POST83
H 3	0.000E+00	0.000E+00	0.000E+00	1.808E-03
Be 10	7.954E-10	9.810E-11	1.939E-11	2.336E-12
C 14	2.917E-08	3.597E-09	7.119E-10	6.198E-10
C136	1.131E-06	2.775E-06	5.486E-07	6.581E-08
Co 60	2.729E-01	6.693E-01	4.931E-01	1.058E-01
Ni 59	6.191E-04	1.520E-03	3.004E-04	1.256E-04
Ni 63	6.869E-02	1.685E-01	3.593E-02	1.526E-02
Sr 90	0.000E+00	0.000E+00	0.000E+00	4.231E-01
Nb 94	7.051E-09	1.730E-08	3.421E-09	5.309E-10
Tc 99	2.034E-07	4.989E-07	9.865E-08	6.665E-05
I129	0.000E+00	0.000E+00	0.000E+00	1.110E-07
Cs137	0.000E+00	0.000E+00	0.000E+00	4.462E-01
Eu152	0.000E+00	0.000E+00	0.000E+00	1.431E-05
Eu154	0.000E+00	0.000E+00	0.000E+00	1.756E-03
Pb210	0.000E+00	0.000E+00	0.000E+00	1.011E-13
Ra226	0.000E+00	0.000E+00	0.000E+00	3.070E-12
Ra228	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ac227	0.000E+00	0.000E+00	0.000E+00	1.820E-11
Th228	0.000E+00	0.000E+00	0.000E+00	6.974E-09
Th229	0.000E+00	0.000E+00	0.000E+00	6.365E-14
Th230	0.000E+00	0.000E+00	0.000E+00	4.331E-09
Th232	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pa231	0.000E+00	0.000E+00	0.000E+00	3.492E-10
U232	0.000E+00	0.000E+00	0.000E+00	1.038E-08
U233	0.000E+00	0.000E+00	0.000E+00	1.665E-10
U234	0.000E+00	0.000E+00	0.000E+00	1.470E-04
U235	0.000E+00	0.000E+00	0.000E+00	4.828E-06
U236	0.000E+00	0.000E+00	0.000E+00	2.172E-06
U238	0.000E+00	0.000E+00	0.000E+00	7.294E-06
Np237	0.000E+00	0.000E+00	0.000E+00	2.373E-07
Pu238	0.000E+00	0.000E+00	0.000E+00	8.314E-05
Pu239	0.000E+00	0.000E+00	0.000E+00	1.520E-03
Pu240	0.000E+00	0.000E+00	0.000E+00	2.148E-04
Pu241	0.000E+00	0.000E+00	0.000E+00	3.862E-03
Pu242	0.000E+00	0.000E+00	0.000E+00	2.213E-09
Pu244	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Am241	0.000E+00	0.000E+00	0.000E+00	2.041E-05
Am243	0.000E+00	0.000E+00	0.000E+00	1.012E-09
Cm243	0.000E+00	0.000E+00	0.000E+00	1.984E-10
Cm244	0.000E+00	0.000E+00	0.000E+00	4.129E-09
Cm245	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm246	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm247	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cm248	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Based on the model ratios, the reported total activity in a shipment is broken down into the activities of the individual radionuclides that are important to risk assessment. Omitted from the list of radionuclides are the short-lived decay daughters of the radionuclides; e.g., Y-90 from the decay of Sr-90 and Ba-137M from the decay of Cs-137. These short-lived radionuclides are generally in secular equilibrium with their parents, and therefore have activities equal to those of their parents multiplied by their respective decay branching ratios.

The activities of the important radionuclides are grouped together according to year of shipment, waste stream, and matrix type. These grouped activities are given in tables in Appendix A. The activities refer to the activities decay-corrected to December 31 of the shipment year.

4.5 Yearly Totals for Disposal

As an overview of waste shipment characteristics, Tables 14, 15, and 16 give the total activities shipped each year, activities shipped yearly for each waste stream, and masses and activities shipped each year for each of the two waste matrix types (metal and debris). The values are based on values from shipment forms. Note that the total activities refer to the reported total activities, not just the activities of the radionuclides important to risk assessment.

Table 14. Activities in yearly waste shipment.

Year	Total Ci	Year	Total Ci	Year	Total Ci
1960	970	1972	1,131.3	1984	2.131E+00
1961	113	1973	1,970	1985	1.740E+01
1962	10,200	1974	6,400	1986	1.671E+O1
1963	4,800	1975	23.4	1987	3.586E+02
1964	3,616	1976	256.174	1988	1.169E+00
1965	1,132	1977	1,300	1989	6.705E+01
1966	3,250	1978	2,000	1990	2.658E+03
1967	1,915	1979	11.08	1991	7.499E-03
1968	2,850	1980	9.824	1992	3.466E+02
1969	1,850	1981	0.5	1993	2.155E+02
1970	1,100	1982	0.923	Total	50,804.58
1971	2,215	1983	7.212		

Table 15. Yearlv activities shinned based on waste stream.

Waste Stream	Year	Activity (Ci)	Waste Stream	Year	Activity (Ci)
TAN-607-2	1960	670	TAN-633-3	1963	3800
	1961	104			
	Total	774	TAN-633-4	1964	3616
				1965	1132
TAN-607-3	1962	10200		1966	3250
	1963	1000		Total	7998
	Total	11200			
			TAN-633-5	1967	1915
TAN-607-5	1970	700		1968	2850
	1971	2215		1969	1850
	1972	1131.3		1970	400
	1973	1970		Total	7015
	1974	6400			
	1975	23.4	TAN-607-6R	1984	2.131E+00
	1976	256.174		1985	1.740E+01
	1977	1300		1986	1.671E+O1
	1978	2000		1987	3.586E+02
	1979	11.08		1988	1.169E+00
	1980	9.824		1989	6.705E+01
	1981	0.5		1990	2.658E+03
	1982	0.923		1991	7.499E-03
	1983	7.212		1992	3.466E+02
	Total	16025.413		1993	2.155E+02
				Total	3.683E+03
TAN-633-2	1960	300	Total	1960-1993	50,804.41
	1961	9			
	Total	309			

Table 16. Yearlv masses and activities shinned based on waste matrix tvne.

	Metal		Debris	
Year	Mass (lb)	Activity (Ci)	Mass (lb)	Activity (Ci)
1960	2,235	720	350	250
1961	1,550	113	—	—
1962	3,410	10,200	—	—
1963	—	—	76,900	4,800
1964	400	750	400	2,866
1965	1,200	1,132	—	—
1966	7,600	3,250	—	—
1967	4,650	1,915	—	—
1968	450	2,850	—	—
1969	2,500	1,850	—	—
1970	600	1,100	—	—
1971	2,750	2,215	—	—
1972	600	980	20,000	151.3
1973	325	1,970	—	—
1974	625	6,400	—	—
1975	80	23.4	—	—
1976	1,276,820	256.174	—	—
1977	170	1,300	—	—
1978	220	2,000	—	—
1979	62,800	11.08	—	—
1980	—	—	1,780	9.824
1981	12,000	0.2	18,000	0.3
1982	93,000	0.923	—	—
1983	—	—	4,000	7.212
1984	—	—	—	2.131E+00
1985	—		—	1.740E+01
1986	—	—	—	1.671E+O1
1987	—	—	—	3.586E+02
1988	—	—	—	1.169E+00
1989	—	—	—	6.705E+01
1990	—	—	—	2.658E+03
1991	—	—	—	7.499E-03
1992	—	—	—	3.466E+02
1993	—	—	—	2.155E+02

Table 17 gives a summary of yearly grouping of activities of the radionuclides important to risk assessment based on whether they are activation products, actinides, or fission products. Co-60 and Ni-63 generally dominate the activities of the activation products; Pu-239, Pu-241, and Am-241 the actinides; and Cs-137 and Sr-90 the fission products. For long-term risk assessments, however, the detailed tables in Appendix A should be used to determine the impact of long-lived radioisotopes—such as Ni-59, Np-237, and Tc-99—which have relatively low activities at present, but may dominate the activities in the long-term future.

Table 17. Yearly breakdown of activities by type of radionuclides.

Year	Activation Products (Ci)	Fission Products (Ci)	Actinides (Ci)
1960	3.715E+02	4.758E+01	3.199E-01
1961	2.404E+00	0.000E+00	0.000E+00
1962	2.254E+02	1.642E+03	2.330E+00
1963	0.000E+00	8.433E+02	8.442E+01
1964	2.658E+02	5.351E+02	5.102E+01
1965	1.554E+02	1.614E+02	1.223E-01
1966	1.291E+03	8.168E+01	5.880E-02
1967	8.439E+02	7.060E+01	5.040E-02
1968	1.135E+03	9.871E+01	2.817E+00
1969	3.608E+02	4.887E+02	5.042E-01
1970	3.221E+02	6.932E+01	6.579E-02
1971	1.118E+01	3.868E+02	3.673E-01
1972	4.936E+00	1.982E+02	2.911E+00
1973	4.728E+02	1.625E+02	1.542E-01
1974	2.856E+03	2.224E-03	0.000E+00
1975	1.199E-01	4.099E+00	3.892E-03
1976	8.480E+01	5.550E-05	0.000E+00
1977	5.670E+02	4.518E-04	0.000E+00
1978	8.702E+02	6.950E-04	0.000E+00
1979	5.559E-02	1.933E+00	1.835E-03
1980	0.000E+00	1.748E+00	1.769E-01
1981	8.953E-02	5.327E-02	5.379E-03
1982	5.763E-02	1.385E-01	1.315E-04
1983	0.000E+00	1.276E+00	1.285E-01
1984	2.437E-01	1.838E+00	1.230E-02
1985	1.990E+00	1.501E+01	1.004E-01
1986	1.910E+00	1.441E+O1	9.643E-02
1987	4.101E+01	3.094E+02	2.070E+00
1988	1.337E-01	1.009E+00	6.750E-03
1989	7.667E+00	5.784E+01	3.870E-01
1990	3.039E+02	2.293E+03	1.534E+01
1991	8.575E-04	6.469E-03	4.328E-05
1992	3.963E+01	2.990E+02	2.000E+00
1993	2.464E+01	1.859E+02	1.244E+00

4.6 Uncertainty Estimates

Uncertainties in the estimates of the shipped activities come from a variety of sources. The largest source of uncertainty is the total activities shipped based on the entries in the shipment forms. Unfortunately, no uncertainty estimates were documented in the shipment forms, nor were there any discussions of the basis of the activity estimates; however, it is possible that the activities were estimated based on mass of waste shipped and some estimated activity concentrations in the waste. The activity concentrations would have depended on the reactor origin of the waste and its irradiation history. It is also possible that the activities were based on dose rate measurements wherever such measurements were made.

Given the total activity in the waste, the method used here to derive the isotopic breakdowns introduces other uncertainties. These uncertainties are in the material composition, its irradiation history, and decay times. Among these uncertainties, the largest probably comes from uncertainties of the impurity levels in the irradiated material, i.e., cobalt for the production of Co-60 and chlorine for the production of Cl-36. For the actinides, particularly for the higher actinides beyond plutonium, most of the uncertainties in their isotopic ratios would come from the irradiation history; i.e., the exposure level of the fuel to neutron fluence. The uncertainty in the decay time after irradiation can also contribute to uncertainty in the isotopic ratios; however, unless the decay time is very short (a few days to a few months) or very long (many years), the isotopic ratios of the radionuclides important to risk assessment are not particularly sensitive to the decay time because (1) the short-lived radionuclides would not have contributed to the total activity and (2) the important radionuclides would not have decayed significantly.

A rigorous analysis of the uncertainties of the quantities of activities shipped from TAN is not possible now because we lack information on the basis of the reported activities. For this study, we assume that the total reported activity had an uncertainty (at the one-sigma level) not more than a factor of 2. The ratios for the isotopic breakdowns calculated here probably have an uncertainty somewhat less than a factor of 2, based on experience with isotope generation and depletion calculations. When these two sources of uncertainty are combined, uncorrelated, the total uncertainty would be a factor between 2 and 3.

To derive a lower and an upper bound for the activities of individual radionuclides shipped, we assume that they are at the three sigma levels removed from the central estimate in a lognormal distribution, i.e., they are at levels 1/8 and 8 times the central estimate, respectively. The tables in Appendix C give the radionuclides important to risk assessment shipped from TAN to the SDA. Each table gives the year of shipment (radionuclides decayed to end of that year), waste stream, and matrix type (metal or debris). The lower and upper bounds are given in the tables in Appendix C.

5. CONCLUSIONS

This report documents the reassessment of Test Area North (TAN) waste disposal shipments sent to the SDA during the combined RPDT and HDT periods (1960–1993).

A major difficulty in making this reassessment has been the limitations of historical documents; i.e., working "backward" from known projects and programs and the records in the RPDT and HDT, and taking into account that not all of the waste sent to the SDA was generated directly from TAN facilities. Because of their size and design capabilities, the Hot Cell and Hot Shop (TAN 607 and 633) received materials from other Site areas as well as from off-site locations for disassembly and inspection; therefore, materials and debris generated from this work were a large part of the materials eventually shipped to the SDA.

Reassessment of the OIS/RWMIS database shows that TAN generated 9.72E+03 m^3 containing 6.64E+04 Ci (ORIGEN2 modeling of isotopic ratios projects 5.080+04 Ci) and concludes that TAN-633 (Hot Shop) and TAN-607 (Hot Cell) accounted for 95% of the waste stream. Approximately 10% of the shipments contained 93% of the total curie waste load sent to the SDA for burial. Also, approximately 40% by volume of the total contaminated waste is buried in Pits 15 and 17, with approximately 36% of the total curie waste load buried in Trenches 26, 49, and 57.

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